RADIO and ELECTRONICS

MARCH 1, 1947

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Chas Weazel

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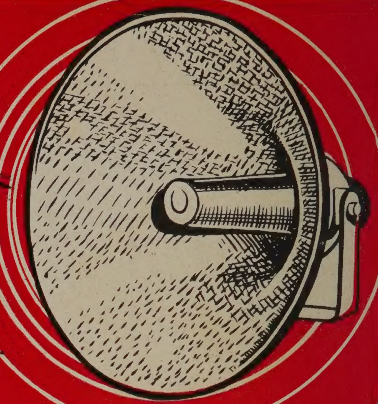

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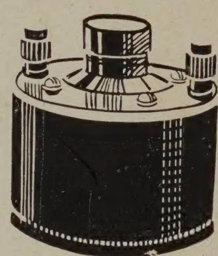

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RADIO and ELECTRONICS

Vol. 1, No. 12 March 1st, 1947

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OUR COVER:

Field-Marshal Viscount Montgomery inspecting mine detection apparatus at a factory of the General Electric Co., Ltd., of England.

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THE TRAINING OF RADIO SERVICEMEN

In our latest Editorial, we were rather outspoken on the subject of the standard exhibited by candidates in the most recent Radio Servicemen's Examination, and wound up by saying that the basis of sound radio knowledge is a solid grounding in elementary electricity and magnetism and mathematics.

While we have yet to find anyone who seriously doubts the truth of this statement, it should be realised that mere knowledge of radio as an academic subject is not the only qualification to be desired in a serviceman, or for that matter, in any kind of radio technician whatever, from the most learned engineer downwards.

Nor do we subscribe to the belief (once common, but now luckily less widespread) that theoretical knowledge is a useless encumbrance, and that practical experience is all. In service work, as in nearly all vocations, experience is a pearl of great price, but even more important is what the Americans call the "know-how."

The serviceman's "know-how" is compounded partly of basic theory, partly of experience, and partly of a third element—the logical approach to a problem.

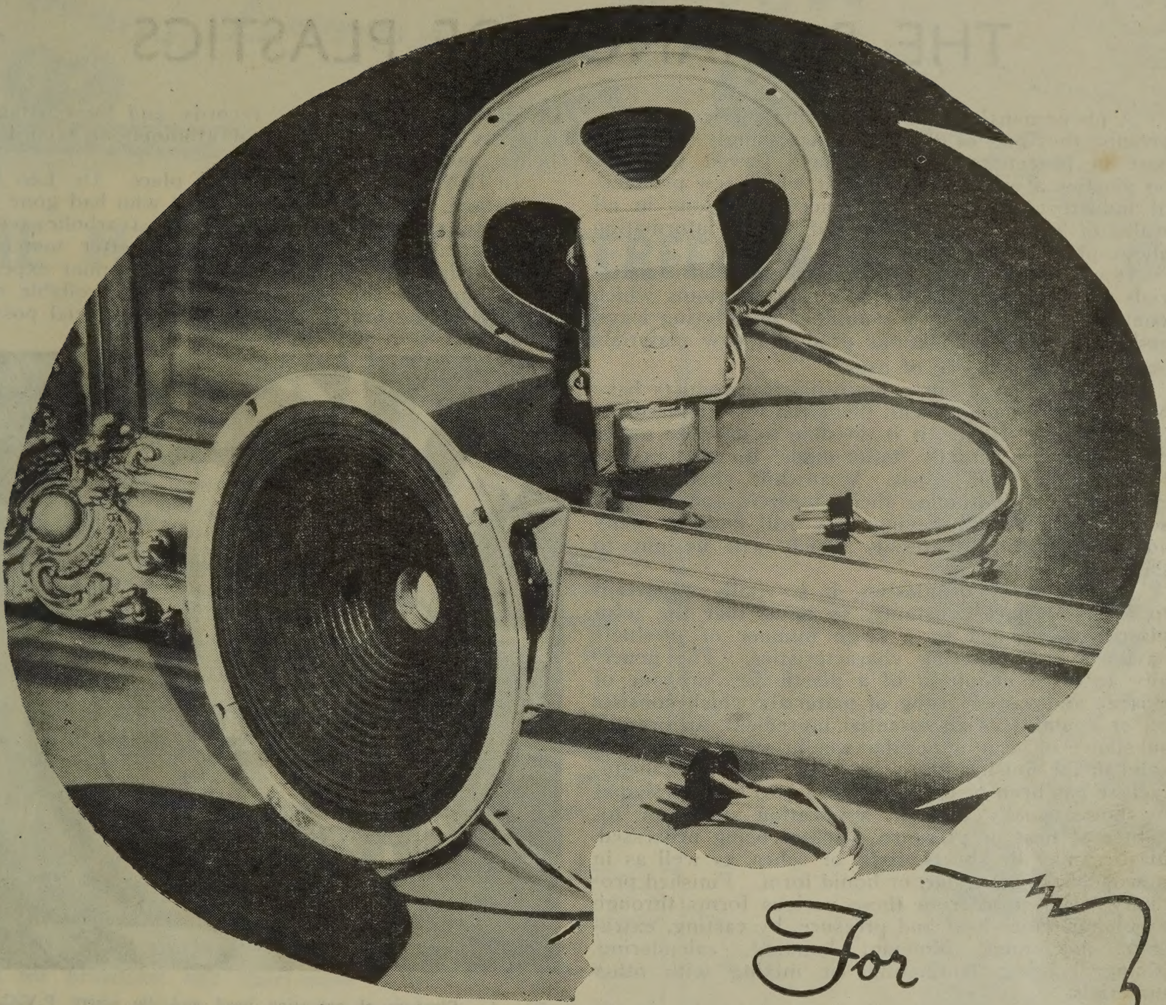
The latter is perhaps the most important thing of all. Some people are born with the ability to size up a problem, separate the pertinent facts from those of no immediate importance, and arrive at an answer very rapidly; others acquire facility in this respect, while some never achieve it. These facts will be corroborated in full by all those who had anything to do with the technical training of radio personnel for the Armed Forces during the War. In a great number of cases, it was found that trainees, with no civilian experience of radio work, and only an *ab initio* course on which to draw as a fund of theoretical knowledge, outshone as servicemen many who had been in the peace-time servicing business for some years.

This point leads back to the question of the training of aspiring servicemen. Under the present scheme of things, the youth wishing to become a serviceman is dependent for his training solely on his own ideas of what is necessary from the point of view of radio theory, and upon the firm for which he works for the acquisition of experience and a knowledge of sound methods—the logical approach that counts so much. If he is apprenticed to a firm which has an excellent man in charge of the service department, the trainee stands a good chance of receiving excellent practical training, but if the reverse is the case, he is penalised in a way which, because of his youth and inexperience, he may not be able to recognise, and may never acquire the "know-how" to which we have referred.

This somewhat haphazard state of affairs should clearly be remedied, but the problem is "in what way?"

One way would be to institute night classes, providing a standardised radio course specifically aimed at the training of servicemen. This course should teach theory to a certain minimum standard regarded purely in the light of a radio serviceman's requirements. It should give as much practical training as possible along repair and maintenance lines, and should wind up with a qualifying examination in which theory and practice play their respective parts. The course should be designed to teach, above all, the scientific method as applied to repair problems, and those in control should have no hesitation in failing candidates whose practical work does not reach the desired standard of efficiency, regardless of their theoretical knowledge.

Such questions as who should be responsible for conducting the course, and in what way recognition for the status of the qualifying examination should be obtained, are at this stage a matter for discussion, but it is clearly in the interests of the radio industry that someone should make a move towards putting radio service training on a sound basis.



THE ROMANCE OF PLASTICS

A phenomenal record of wartime service, and the promise they give of playing an increasingly important part in peacetime activities, have served to focus on plastics a world-wide interest which few products of industry have ever experienced. Persons in all walks of life have been prompted to seek information about plastics.

It was learned that commonly-known basic materials are made up of links or chains of atoms which could be broken down or combined in differing ways, and that such combinations produced new materials having a wide variety of uses.

To date, about thirty basic plastic products have been developed which lend themselves to hundreds of formulations. Hence, it is possible to produce materials which are actually "tailor-made" for the purpose to which they will be put. Meanwhile, chemists and engineers are continuing their research, and there is sound reason for believing they will develop many additional plastic materials which will be put to thousands of uses.

In any study of plastics, it is vitally important to keep the fact constantly in mind that the term plastics is applied to a large number of products having widely-differing characteristics. The generally accepted definition of a plastic is: Any one of a large and varied group of materials which consists of, or contains as an essential ingredient, an organic substance of large molecular weight and which, while solid in the finished state, at some stage in its manufacture has been or can be formed into various shapes by flow, usually through application singly or together of heat or pressure. Before being processed, plastics may be sheets, rods, or tubes, as well as in powder, flake, granular; or liquid form. Finished products are derived from these various forms through moulding under heat and pressure, by casting, extrusion, machining, blowing, bonding, calendering, gluing, coating, laminating, or mixing with other materials.

The origin of plastics is another example of the age-old search for new and better materials to replace natural ones used up because of utter disregard for future needs, or to perform functions more satisfactorily than materials available. Back in 1868, when a shortage of ivory for making billiard balls existed, a prize was offered for an equally suitable material. John Wesley Hyatt, an Albany, New York, printer with an inventive turn of mind, hit upon a method of mixing cellulose nitrate, produced from cotton linters and nitric acid, with camphor. The product was named celluloid, and, when found to have many uses, it became the first commercially accepted plastic. In addition to its use in billiard balls, celluloid was employed for collars, cuffs, and shirt fronts. Later, window-curtains were made from it for early models of motor cars, and, when coloured pink, it was widely used to replace hard rubber in making denture plates.

Despite this opening of the door on the world of synthetic materials, the next fifty years brought only four developments. In 1895, a natural resin, shellac, produced by an insect found in Asia and Southern India, was utilised to make gramophone records. To-day, shellac is also employed in the manufacture of high-voltage insulators, records, and for coatings, whereas an improved type of gramophone record is being made from plastics.

In 1909, a major advance took place. Dr. Leo H. Baekeland, a noted Belgian chemist who had gone to America, experimented with phenol (carbolic acid) and formaldehyde while seeking a better material than shellac. While others had made similar experiments, he was the first to obtain a controllable reaction and the first to exploit the commercial possibilities of this resinous material. Using greater heat and a catalyst (a substance which speeds chemical reaction but remains unchanged itself), he produced a resin that could be cast to desired form, as well as compounds that could be moulded under heat and pressure into a variety of products. At this same time, he also produced laminating varnishes and worked on many other uses. In addition, he incorporated other materials known as fillers, in the moulding compounds, thereby giving them improved or additional properties.

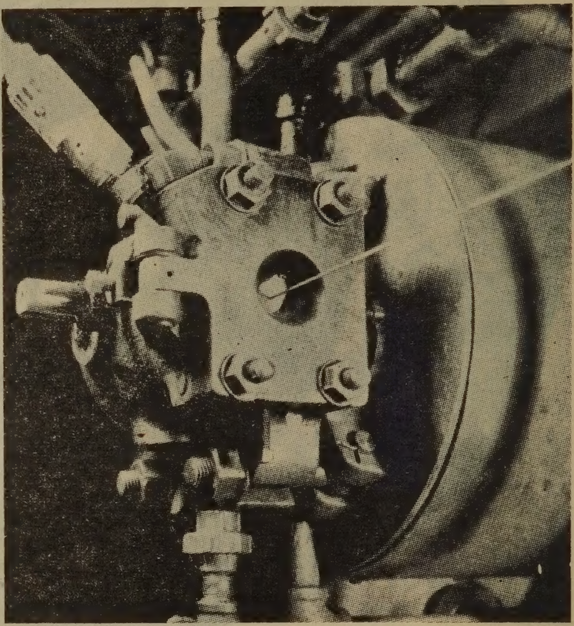


Fig. 1. Close-up of extrusion head and die where P.V.C. is extruded over wire at proper temperature and in required thickness to ensure important insulating qualities. Conductors are from approximately 1/16-inch to 1/8-inch in diameter.

That same year, bitumin plastics, more commonly known as cold moulded, were developed from asbestos, asphalts, coal tar, stearin pitches, natural and synthetic resins, and oils. A heat-resistant, insulating material, it is used in the electrical, wiring device, and automotive fields, being moulded under pressure at or near room temperature to desired shape, then baked in ovens to ensure holding of that shape.

In 1919, casein plastic was introduced commercially in America. Originally produced in Europe

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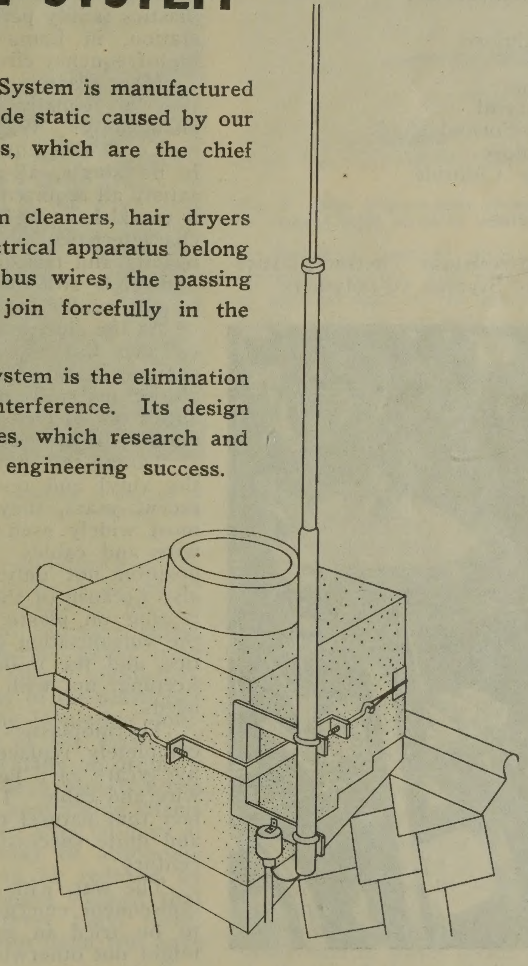

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about 1890, it is made from the protein of skim milk reacted with formaldehyde.

About twenty new plastic compositions, which are described later, have been developed or introduced commercially, and a tremendous increase in the annual production of plastics has taken place. The order in which these new plastic resins have appeared is:—

1926—Aklyd
Aniline-Formaldehyde
1927—Cellulose Acetate
1930—Urea-Formaldehyde
1931—Acrylic
1932—Cellulose Acetate Butyrate
1936—Methyl Methacrylate
Vinyl
1937—Ethyl Cellulose
Lignin
Polystyrene
Vinyl Butyral
1939—Melamine-Formaldehyde
Ethylcellulose
Vinylidene Chloride
1942—Allyl
Polyethylene
1943—Silicones
1944—High heat-resistant Thermo-plastics such as Styrene co-polymers

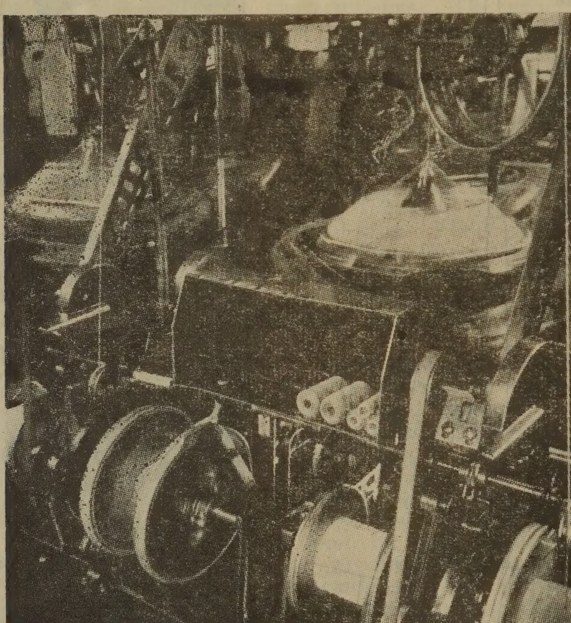


Fig. 2. Polyethylene insulated coaxial conductors are receiving a copper shield braid to provide return circuit, while P.V.C. plastic conductors receive glass braiding and coloured yarn for circuit identification. Polyethylene sheath is then extruded over copper shielded conductors to provide circuit identification and resistance to moisture and chemicals.

Plastics offer the electrical industry an unusual combination of advantages that have aided in the solution of long-standing, perplexing insulating problems. True, there are many other types of insulating materials—paper, textiles, fibre, quartz, glass, ceramics, rubber—that always have served and will continue to serve many dielectric needs. Plastics are particularly serviceable because of the ease with which they can be fabricated into various shapes, the simplification in design which they frequently make possible, their combination of good mechanical and electrical properties, their permanence, and their comparatively low cost. These and other advantages, such as availability in many forms ranging from insulating varnishes and tapes to moulded, laminated, cast, and extruded shapes, have led to their widespread use throughout all branches of the electrical industry, wherever insulating problems are encountered in the generation, transmission, control, and use of electrical energy. Thus, we find members of the plastics family performing equally well in the central station, in home appliances, and in the sensitive high-frequency circuits employed in electronic devices.

Most plastics are good electrical insulators. Are they all equally good? Can they be used interchangeably? Why so many plastics?

To all these questions there is one answer. There is no single, all-purpose plastic material that will satisfy all requirements. If there were such a product it would have to be endowed with such contradictory characteristics as rigidity and rubber-like flexibility, opacity and transparency, hardness and softness, low and high softening temperatures, and many other equally conflicting properties.

As the electrical industry has continued to expand, so also has the plastics industry, so that to-day engineers and designers have many new types of plastic materials at their command. Their potentialities as electrical insulating materials have been readily discerned.

Taking the spotlight among the thermoplastics are the vinyl and resins. Although developed only in recent years, they are to-day among the materials most widely used in the insulating and jacketing of wire and cables. They have reached this eminent position not only because of their properties, but also because of their ease of processing. Their processing on plastic extruders, which eliminates both the vulcanisation process, with its attendant difficulties, and the milling process, proved a life-saver in keeping up with the war's tremendous electrical needs.

Thermoplastics and synthetic rubbers have almost completely replaced natural rubber within the last five years as a jacketing and insulating material on wire and cable. This has come about in spite of the fact that natural rubber had been used continuously and quite successfully in this application for half a century.

The war, with its shortage of natural rubber and consequent emergency needs, caused the vinyl resin to be tried in many applications for which they might not otherwise have been considered. In many such instances, they have proved superior and now, occupying a strong position because of their outstanding characteristics, will doubtless be continued in such uses. Consequently, usage of these resins, which had reached substantial proportions before Pearl Harbour, was widely expanded during the war.

During the war years, nearly all the purchases of the vinyls by the wire and cable industry were ear-marked for the armed services to be made into insulation and protective jackets on wire and cable, with the navy taking the larger share. The impetus

given to vinyl resin production by war needs is indicated in its annual production figures, showing 18,000,000 pounds total production in 1940, 83,000,000 pounds in 1943, 114,000,000 pounds in 1944, and an estimated 125,000,000 pounds in 1945.

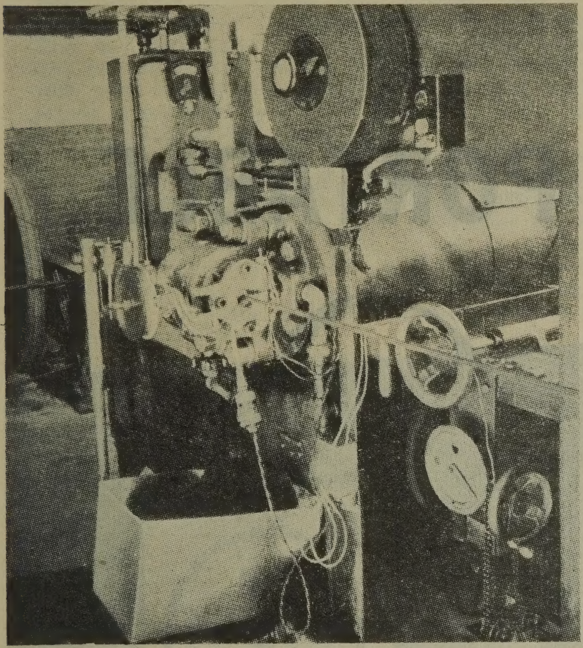


Fig. 3. In this extruder, P.V.C. plastic jacketing is applied to cable as tough protection against abraision, oils, moisture, and adverse temperatures.

Probably the most outstanding superiority of the vinyl chloride plastics over natural rubber lies in its excellent aging characteristic. For example, because of the resistance of the vinyls to ordinary aging, the standing aging tests, such as the Greer oven and oxygen bomb tests, are no longer significant, except as a measure of the volatility of the plasticiser and the resultant hardening of the insulating compound. However, this extraction of the plasticiser occurs so slowly that tests, run normally on ordinary rubber compounds for seven to 14 days, require a run of 60 days at 70 deg. C. to detect appreciable effects on the vinyl chloride plastics. Even after 60 days at 70 deg. C., the tensile strength may be absolutely unaffected and the elongation may be reduced by only a few per cent. It is therefore evident that ordinary aging means little to these vinyl resins and that ordinary wire insulated with them will have a very long life.

These vinyl chloride plastics are remarkably resistant to lubricating oils and the ordinary solvents; but will be softened somewhat by certain lacquer solvents, the aliphatic and aromatic ketones, the acetic anhydrides, the aromatic amino compounds, and some other organic compounds containing chlorine, bromine, or nitro groups.

Contrariwise, they will harden as a result of plasticiser volatilisation in very high temperature air or very high temperature water and other liquids where a leaching action may occur. In either case the effect on the physical and electrical properties is not nearly as severe as that found with the use of natural rubber.

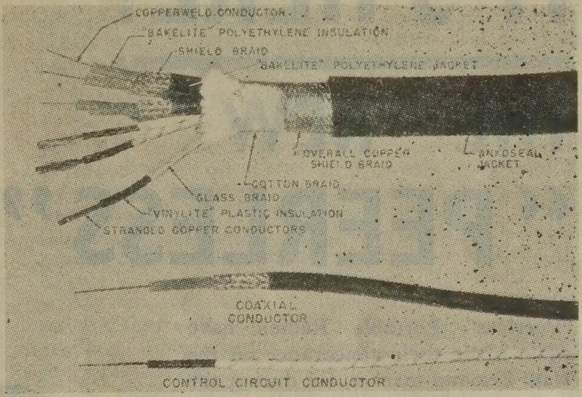


Fig. 4. This diagrammatic photograph illustrates a typical set-up for co-axial cable insulated with polyethylene and P.V.C. plastics.

Because another physical property of the vinyl chlorides, resins, and plastics has proven so superior to natural rubber, the navy, during the war, took the lion's share of the polyvinyl resin insulated wire produced. Further, most of the wire going on all naval craft was insulated with polyvinyl resin. That property, its flame-proofness, has been such an improvement over the standards established for natural rubber that the navy has designed more severe flame tests than those previously used by the industry. The value of this flame-proofness to the home wiring field can be appreciated when it is learned from the fire underwriters that the second largest cause of home fires is that due to electric-wiring faults.

In addition to their exceptional physical properties, the polyvinyl resins possess an outstanding dielectric strength, which ranges from 400 to nearly 2000 volts per mil, depending upon the wall thickness tested and the type of test applied. A good average figure for ordinary wall thicknesses and average tests might be 700 to 800 volts per mil. A dielectric strength of such values combined with excellent physical qualities has proven particularly useful on wire and cable, where it has been possible to use thinner walls of insulation. This, in turn, has been a means for saving weight, cutting down space requirements, and generally making it possible to carry up to twice as much power in a given size of conduit, an important factor in these days of increased motor and lighting loads.

It should be mentioned at this point that long immersion in water seems to make negligible changes in the insulation resistance of these materials, even after 60 days in water at 60 deg. C. The change in dielectric constant and loss factor at 25 deg. C. in water amounts to an increase of 10 to 15 per cent. after 20 days immersion. The decrease in dielectric strength over the same period is approximately 10 per cent.

If there was ever any question as to the future of the polyvinyl resins for wire and cable use, the war definitely settled that once and for all. In the

(continued on page 48)

A Pre-Amplifier for Moving-Coil Pick-ups

In the past, gramophone pick-ups have had anything but the well-known "flat response" that is so much sought after in amplifiers and loud-speakers. This has been due in part to the fact that moving iron and crystal pick-ups are very difficult to construct with such a response, so that only the very highly priced instruments used in broadcasting studios have even approached this standard.

There is a second and not so well known reason, however, and it is that **a flat pick-up response curve is not desirable in any case, when commercial recordings are to be reproduced.** This is because the frequency response of commercial records is not itself flat, being purposely reduced at the low frequency end of the scale. In order to explain why this is done, it is necessary to say a few words about the process of recording itself.

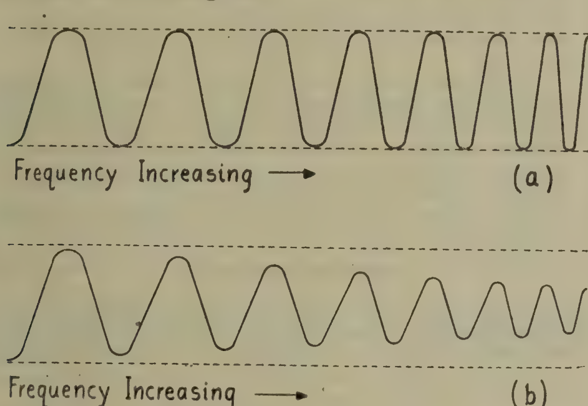


FIG. 1

Illustrating the difference between constant amplitude recording (a) and constant velocity recording (b). These are not to scale, in that the groove in an actual record must not cross the direction of movement of the record at more than 45 degrees.

TYPES OF RECORDING

There are two different kinds of lateral cut recording, known respectively as constant amplitude and constant velocity. In the former, the amplitude of the cutting needle movement is held constant, irrespective of frequency, for a constant input to the cutting head. When such a record is played back, the amplitude of the playing needle movement follows the same law. Now, the output of a pick-up of the moving iron or moving-coil type depends solely upon the velocity of the side-to-side motion of the needle. This velocity is clearly proportional to frequency, since if twice as many lateral movements are made in a given time (indicating twice the frequency), and if the distance travelled during the movement is the same as before (constant amplitude), the speed of movement must have been doubled. Therefore, the voltage output of the pick-up will be directly proportional to frequency, and the record-pick-up combination does not have a "flat" frequency characteristic. Rather does it have a response in which the output voltage is proportional to frequency. This kind of recording is not, for this very reason, suitable for the manufacture of commercial pressings, but is used in certain types of acetate disc instantaneous playback recording.

CONSTANT VELOCITY RECORDING

In this type of recording, the cutting head is designed so that for a constant input, the amplitude of the needle movement is inversely proportional to frequency. It follows from this that for a given level, the velocity of the needle movement is constant, irrespective of frequency. So, when such a record is played with a magnetic or a moving-coil pick-up, the output is constant, irrespective of frequency. Thus, it can be seen that constant velocity recording, in conjunction with a normal pick-up, gives a frequency response curve that is straight and flat at all parts of the audio range.

It would seem from the above that constant velocity recording should be the type to be used in the making of commercial records for home use.

COMBINATION OF BOTH

Up to a point this is true, but in actual practice, commercial discs are made by a combination of both methods. Let us try to see why. Figs. 1a and b illustrate the appearance (not to scale) of portion of two identical "gliding tone" recordings, made by the constant amplitude and constant velocity methods respectively. In each case, the maximum allowable excursion of the groove is shown by the dotted lines. (Obviously there must be a maximum allowable movement, or else the groove will cut into these on either side of it.) A glance at Fig. 1 shows that with constant velocity recording, the amplitude of the needle movement increases as the frequency decreases. For this reason, if constant velocity recording is used over the whole frequency range, one of two

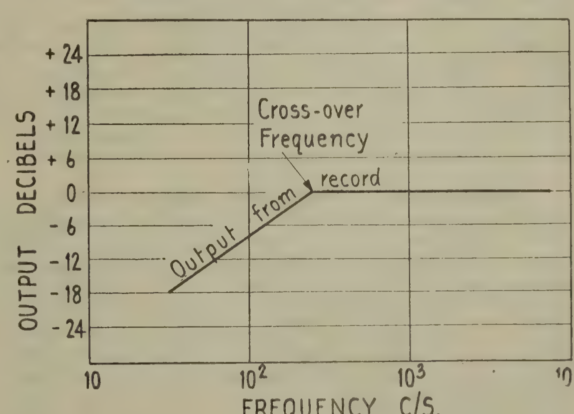


FIG. 2

Response of a commercial record with a crossover frequency of 250 c/sec. when played with a velocity-operated pick-up.

things can happen. Either the amplitude at the highest frequencies becomes so small that these frequencies are lost in the surface noise which is inherent in all discs, or else, if the highest frequencies are adequately recorded, the amplitude at low frequencies

becomes so great that the grooves overlap and the record will not play.

This means that any attempt to use constant velocity recording over the **whole** audio range must result either in a restricted frequency response, or in a very low overall amplitude, with consequent degradation of the signal-to-noise ratio.

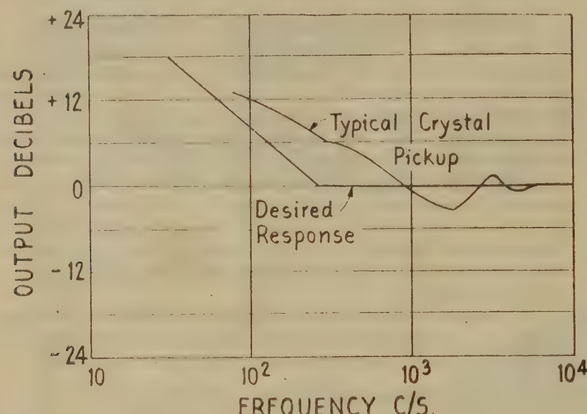


FIG. 3

Curves showing the theoretically required response curve for a pick-up to obtain a flat response from the commercial record whose characteristics are depicted in Fig. 2. Also shown is the measured response curve of such a record when played with a typical crystal pick-up without equalisation.

In order to overcome this difficulty, commercial discs use a combination of both methods. Constant velocity is adhered to from the highest frequencies down to, say, 250 c/sec., from which constant amplitude is used, down to the lowest recorded frequency.

In this way, the advantages of both types are obtained, at the expense of a flat overall response characteristic.

From what has been said, it is apparent that the frequency response obtained from a commercial record using a normal pick-up will be somewhat as in Fig. 2. Here, the response is "flat" from high frequencies down to the cross-over frequency, in this case 250 c/sec., after which there is a linear drop in response down to the lowest recorded frequency.

NECESSITY FOR EQUALISATION

Since commercial discs are made in the manner described above, it is apparent that any pick-up at all requires some form of frequency compensation, or equalisation, if the overall response of record, plus pick-up, is to be "flat." As mentioned before, all normal types of pick-up (including crystal ones) have a response which results in a flat characteristic when they are used with constant velocity recordings. Flat, that is, in theory, for all but the very best have irregularities in their response curves, due to resonances in both the electrical and mechanical part of their make-up. Cheap magnetic and crystal pick-ups are quite poor in this respect, and are often used without any proper compensating circuits. The fact that they give reasonable results at all is that in their case, the bass resonance which occurs is used to lift the response at the low frequency end of the scale, giving an overall characteristic which has some sort of approach to what is required. With crystal pick-ups in particular the bass response may be raised by increasing the value of the load resistor. Fig. 3 shows the ideal response required from a pick-up which is to be used with normal records, and at the same time the actual response curve of a typical crystal pick-up used with a fairly high value of load resistor.

MOVING-COIL PICK-UPS

The primary purpose of this article is to describe a compensated pre-amplifier circuit for use with the recently available moving-coil pick-ups, so that a few words about the characteristics of these instruments are not out of place.

The moving-coil pick-up is one of the nearest approaches yet achieved to a perfect velocity-operated pick-up, without undesired humps or valleys in the response curve. Thus, it would have a perfectly flat response down to the lowest frequencies if it were used with a pure constant velocity record. If used without compensation on a commercial disc, the response would be flat down to the cross-over frequency, and then would decrease with frequency, so that reproduction would lack bass and sound thin or scratchy.

It is absolutely essential that a proper compensating network be used with this type of pick-up. The circuit given in Fig. 4 is that of a pre-amplifier, designed both to give appreciable amplification and to have a response curve as close as possible to the one in Fig. 3 labelled "Desired Response."

The actual curve of this pre-amplifier is given in Fig. 5.

THE CIRCUIT

It will be noted that the circuit begins with a 50 : 1 step-up input transformer. This is because, like moving-coil speakers or microphones, the moving-coil pick-up is a low impedance device and gives an exceedingly low output voltage. There is no need for us to specify here exactly what type of transformer should be used, since it is so important to the proper operation of the pick-up that the manufacturers always provide a suitable one with the pick-up. Needless to say, this transformer must have a flat response over the entire audio range covered by the pick-up itself.

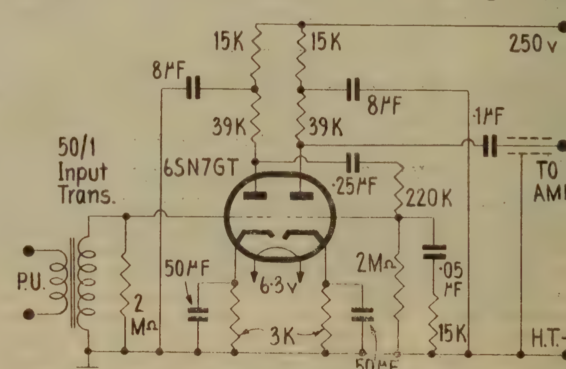


Fig. 4. Circuit of pre-amplifier suitable for any moving-coil pick-up which has a pure velocity operated characteristic.

The pre-amplifier consists of two stages of resistance coupled amplification, using a dual triode tube, type 6SN7-GT. The first thing to be noted about

the circuit is that heavy decoupling filters are inserted in both plate leads. These are absolutely necessary, both to assure stability when the pre-amplifier is run from the same H.T. supply as the main amplifier,

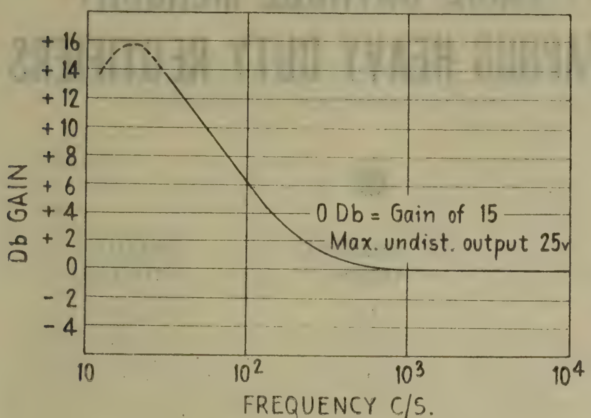


FIG. 5

Response curve of the pre-amplifier circuit shown in Fig. 4. Note that it is not possible to give a sharp transition as in Fig. 3, but that the frequency response commences to rise at about 800 c/sec.

and to ensure that the best possible low frequency response is obtained from each stage. The actual bass-boosting network is in the grid circuit of the second stage, and gives the pre-amplifier the characteristic shown in Fig. 5. The gain at medium and high frequencies is 15 times, so that sufficient output is obtained to feed any normal amplifier. If it is desired to construct the pre-amplifier on a separate chassis, a cathode follower using a 6J5 could usefully be incorporated in the pre-amplifier, and would eliminate hum pick-up, or high frequency loss due to a shielded output cable.

ANY PICK-UP

This pre-amplifier should be quite suitable for any type of moving-coil pick-up which itself has a flat response as a velocity-operated device. This is because the compensation required is a function of the record rather than the pick-up if this is the case. No volume control has been inserted in the circuit, as the level is still quite low, and volume control is best effected **after** the bass compensation has taken place, namely in the main amplifier.

Some rather odd values of resistor have been specified in the circuit, but any standard values within 5 or 10 per cent. of the nominal values given should have very little effect on the response curve. For instance, two 20k. resistors in series will be quite satisfactory for the 39k. plate load resistors, and 250k. instead of 220k. will have a negligible effect on performance.

Before leaving the pre-amplifier, readers should be warned that with the average magnetic or crystal pick-up, the bass compensation provided by the present circuit will be much too great, since these pick-ups normally rely on arm resonance and similar effects, as indicated above.

A New Circuit Using Triodes for R.F. Amplification in Receivers

Just as the introduction of the Infinite Impedance Mixer paved the way for receivers with much better than average signal-to-noise ratio, so does this new R.F. amplifier circuit open up possibilities for even better results in this direction than can be achieved by a triode mixer alone.

For almost twelve months now we have been at some pains to stress the great importance of signal-to-noise ratio in the performance of receivers. Better than this, we have introduced the infinite impedance mixer in support of these contentions, and it is safe to say that no new circuit for many years has created so much interest and favourable comment among experimenters.

The circuit presented here will, we hope, stimulate as much interest on the part of readers as did the former one. It should do, if results are anything to go by, for by using triodes not only as mixers, but as R.F. amplifiers, too, **it is possible to reduce tube noise in a receiver to its absolute theoretical minimum.**

WHY USE TRIODES?

If we set out to design a receiver to be as noiseless as possible, we find ourselves up against one or both of two difficulties. The first of these is shot noise in the tubes themselves, and the second is thermal agitation noise arising in the first tuned circuit. Depending upon conditions, sometimes the former determines the overall signal-to-noise ratio of the receiver, and sometimes the latter. Broadly speaking, the main condition referred to is that of frequency, for at low frequencies noise arising in the first tuned circuit can swamp that arising in the first tube, while at high frequencies tube noise tends to become the controlling factor.

From this it is obviously of greater advantage to have the least possible valve noise when on the higher frequencies, but even so, the use of triodes enables shot noise to be kept to a minimum under all conditions, and this represents a substantial gain in receiver performance at any frequency.

Before there were any R.F. pentodes, triodes were perforce used as R.F. amplifiers. As in triode transmitting amplifiers, receiver circuits had to be neutralised in order to prevent self oscillation. This created a major difficulty, since proper neutralisation in receiver circuits is quite a difficult problem—so difficult, in fact, that the introduction of screen grid tubes which required no neutralisation and gave higher gain as well saw a complete swing away from triodes as R.F. amplifiers, quite regardless of the fact that then, as now, these tubes provided the least possible valve noise.

Now, however, the situation is quite different. Gain is easy to come by, modern tubes and components being what they are, so that sig./noise ratio is the limiting factor in the performance of a receiver. Thus it is that triodes with their inherently low shot noise **must** be used for mixing and for R.F. amplification if tube noise in a sensitive receiver is to be reduced to a minimum.

THE CIRCUIT

Since neutralisation of some kind is required if triodes are to be used at radio frequencies, their successful employment must depend on the development of a circuit which requires no neutralising adjustment.

The circuit given here was developed by Sziklai and Schroeder([1]), two engineers of the R.C.A. laboratories, in a successful attempt to design a low-noise pre-amplifier for extending the useful range of television receivers. Sziklai and Schroeder termed their circuit the "cathode-coupled twin triode amplifier circuit." In Fig. 1, the two triodes have been drawn as separate tubes for clarity, but for most purposes a twin triode is quite satisfactory. The

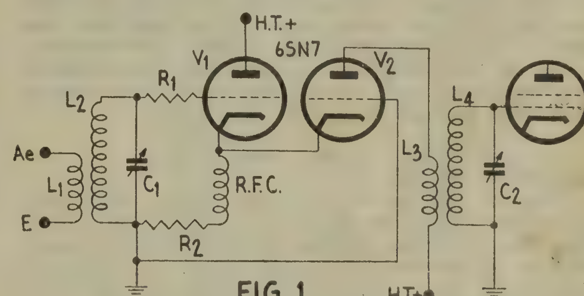


FIG. 1

Circuit of the new R.F. amplifier stage. R_1 should be 1000 ohms, which is satisfactory at broadcast, and at high frequencies may be reduced in proportion. R_2 for a 6SN7 should be 500 ohms. For detail on R.F.C. see text.

operation of the circuit is quite simply explained. V_1 acts as a cathode follower. The input is applied to its grid through a tuned circuit in the usual way. The choke R.F.C. acts as the cathode load, so that an unamplified signal appears at the cathode of V_1. As was pointed out in an earlier article([2]), the cathode follower circuit is quite stable at radio frequencies as long as certain precautions are taken, and requires no neutralisation, so that, as far as the cathode of V_1, the circuit is quite straightforward. The second half of the circuit, V_2, is connected as a grounded-grid amplifier. That is to say, the grid is earthed, signal voltage is applied to the cathode, and the output is obtained from the plate circuit.

If a triode is used in the conventional or grounded cathode circuit, there is positive feedback from the plate circuit to the grid circuit through the grid-plate capacity of the tube. At radio frequencies, when tuned circuits are used in plate and grid circuits, this feedback is sufficient to maintain oscillation. In fact, this scheme is well known as the tuned-plate-tuned-grid oscillator circuit. However, when the grid of a triode is earthed, it acts as an electrostatic shield between the plate and the cathode, so that

tuned circuits may be attached to these electrodes without oscillation occurring. The grounded grid circuit may, therefore, be said to be self neutralised, as prevention of feedback is inherent in the circuit and requires no adjustments whatever. Thus, the grounded-grid circuit fulfils the main stipulation which we made above. Unfortunately, this circuit on its own has a very low input impedance, so that if a tuned circuit were placed between cathode and earth, the shunting on it would be so great that no tuned-circuit amplification or selectivity would be obtained. However, by combining the grounded-grid stage with a cathode follower input stage, the inventors of our circuit here have removed this difficulty. The whole circuit has a normally high input impedance, and a tuned circuit is placed at the first grid without loss. The cathode follower has a low output impedance of the same order of magnitude as the input impedance of the grounded-grid stage, so that there is no loss in transferring the signal to the latter. The grounded-grid tube gives normal amplification, and provides its output through a radio frequency transformer in the usual manner.

Thus, we have a circuit which provides considerable gain, is quite stable, and has the inherently low noise of any amplifier using triodes. Furthermore, it can be used with readily obtainable and inexpensive tubes, and with normal coils of the type usually used with pentode R.F. amplifier stages.

PRACTICAL DETAILS

(1) TUBE TYPE:

One of the most important things about the successful use of this circuit is the choice of a suitable tube or tubes. Sziklai and Schroeder in their original experiments used a 6J6, which is a miniature twin triode with common cathode and the high mutual conductance of 5 ma./v. per section. This type is not yet procurable in this country, so that it is necessary to use other types.

The prime necessity is a valve with reasonably high mutual conductance. The reason for this is that a high gm. tube has a close-wound grid, and close spacing between grid and cathode. This means that the grid is able to form an efficient shield between cathode and plate. If it cannot, the shielding may not be sufficient for the grounded-grid circuit to prevent oscillation.

For this reason the 6SN7-GT was chosen for our first attempts to make the new circuit work. This tube is a twin triode, each unit having electrical characteristics identical with that of the 6J5. The mutual conductance of each section is 2.6 ma./v. with 250v. on the plate and normal bias, which is higher than the figures for the other available double triodes, e.g., the 6SL7.

Further, the gain in the triode stage needs to be as high as possible, and this is greater the higher the mutual conductance of the tube used.

In an experimental hook-up which worked on the broadcast band, the 6SN7 was found to be quite suitable, and gave a measured gain of between 50 and 60 over the band, using normal aerial and plate coupling coils designed for use with pentodes.

(2) THE CATHODE CHOKE:

The success of the circuit can obviously depend upon the design of the choke used in the cathode circuit. This must clearly possess a high impedance at all parts of the tuning range of the receiver, since if the choke has any "holes" in its impedance-frequency curve, the gain of the stage could be seriously reduced at the frequency of the said holes. For ease of application, the circuit needs to be workable with standing types of R.F. choke. As previously mentioned, the first experimental set up was on the broadcast band, so that here the logical choice was a standard 10mH. choke designed for use at these frequencies.

This choke was found to be entirely satisfactory, as long as the grid-stopper, shown in Fig. 1, is used in the input section of the stage.

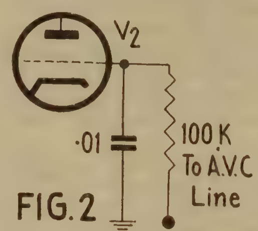


FIG. 2

Showing how A.V.C. may be applied to V_2 in the circuit of Fig. 1. No other circuit alterations are necessary.

An important point in connection with the cathode choke is this:—Radio frequency chokes are normally designed to have high inductance, but very low distributed capacity. Thus, although the self capacity is kept as low as possible, some still exists, so that the choke is really a low-Q parallel-resonant circuit Now, since the parallel resonant frequency of the choke can and usually does lie somewhere within the range of frequency intended to be covered, the choke's impedance will, therefore, become capacitative at frequencies higher than the self resonant frequency. If this occurs, there will be a possibility of the cathode-follower section of the amplifier stage oscillating, unless a grid stopper is used. This is the real reason for the inclusion of this component in the circuit. Its presence in any case can do no harm, as it will not affect the amplification obtained from the stage, and it is a worthwhile insurance against instability.

For short-wave use, a 2.5 mH. choke will be quite satisfactory for frequencies from 80 metres to 20 metres or even lower.

In all-wave receivers, there is no necessity to switch in different sizes of choke for the various wave-bands, since the short-wave and broadcast chokes will function quite independently if placed in series.

The possibility was envisaged of using low-inductance chokes, such that their impedance is inductive over the entire wave-range, but this idea was discarded, as quite a number of them would be needed to cover the whole range of a band-switching receiver, and besides, the variation of stage gain over the individual bands would probably be excessive with such an arrangement.

(3) GRID BIAS:

The grid bias for the cathode coupled stage is obtained from a single cathode resistor. The arrangement is quite normal, except that no useful purpose is served by bypassing the resistor. The usual bypass condenser is therefore omitted. A value of 500 ohms is satisfactory for the 6SN7, and gives it a plate current of about 14 ma. total, and a bias of 7½ volts.

(4) USE OF A.V.C.:

For some purposes, there would be a distinct

disadvantage in this circuit if it were not possible to apply A.V.C. However, experiments indicate that, with care, A.V.C. can be successfully applied to the cathode coupled twin-triode amplifier. The manner of doing this is illustrated in Fig. 2, in which is drawn the revised grid circuit of the section marked V_2 on Fig. 1. Now, the grid of V_2, instead of being earthed directly, is connected to earth through a 0.01 mfd. condenser. A decoupling resistor of 100k. is inserted in series with the grid, and the free end of this resistor is attached to the A.V.C. line.

This scheme works quite satisfactorily, with one reservation. In town areas, where very strong local signals exist, and the stage is used on the broadcast band, the range of control is not sufficient to prevent the stage from overloading, if the full A.V.C. voltage is applied to it. In these circumstances it is necessary to pick off a portion only of the available A.V.C. voltage, and apply this to the 6SN7 through a separate A.V.C. filter.

However, for short-wave use, or in situations where there are no powerful local stations, the full A.V.C. voltage can be used.

EXPERIMENTAL WORK CARRIED OUT

In testing this new circuit, an experimental "front end" was constructed consisting of a 6SN7 cathode coupled R.F. stage, and a 6SN7 used as an infinite impedance mixer and oscillator. This hook-up functioned on the broadcast band only, and used conventional aerial, oscillator, and R.F. coils. In addition, it was used with the I.F. amplifier described in the January, 1947, issue of "Radio and Electronics" in order that gain measurements and an estimate of its noise level could be made.

As mentioned above the gain of the R.F. stage over the broadcast band with this set-up varied between 50 and 60, measured between aerial terminal and mixer grid. This represents about two-thirds the gain given by a normal pentode stage using the same coils, but in view of the exceedingly low noise level, this is not at all serious. Using one I.F. stage and a typical audio amplifier, the sensitivity of the complete hook-up was 2 microvolts for 50 mw. output, the signal generator being modulated 30 per cent. at 400 c/sec.

It was not possible, owing to the lack of a shielded test room, to obtain measurements of the signal-to-noise ratio, but this was so high as to be very noticeable by ear alone.

Our premises are in a particularly noisy locality in Wellington, but it was still possible to judge the set noise by the extent that the audible noise increased when a weak carrier was being tuned in. It was found that the usual carrier hiss was almost entirely absent. In fact, a weak unmodulated carrier could be entirely missed for this reason. Even in the midst of the man-made external noise, 1YA could be received throughout the day. True, it was not always readable, as the outside noise was so violent, but on a normal receiver in this locality, set noise prevents even the existence of 1YA from being detected.

In making these tests there was no doubt in our minds at all that the expected low-noise performance of the circuit was being realised.

SHORT-WAVE USE

Since the circuit was originally developed for use at television frequencies, and since we had made it

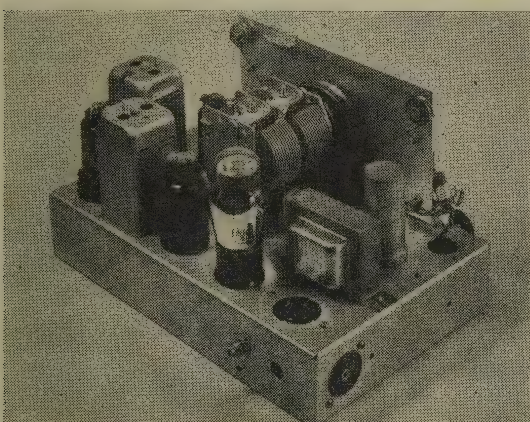
(Continued on page 48.)

THE RADEL "VIBRATOR FOUR"

This receiver, designed to run off a 6-volt accumulator, has a vibrator H.T. supply requiring no rectifier valve, and giving 135 volts at 25 ma. The audio output power is half a watt, and the sensitivity is almost equal to that of a five-tube A.C. operated set.

VIBRATOR SET CONSIDERATIONS

For installation on yachts and launches, for running in a car or trailer while on camping trips, and in other similar situations, a vibrator-operated set is the most economical that can be built. In the first place it uses heater-type tubes which are rugged and non-microphonic; it has almost the sensitivity of an A.C. set with a similar valve arrangement, and it can have up to half a watt of audio output. All this is attained at the operating cost of practically nil, since the whole receiver draws only very few



View of the completed receiver. Note the sockets for connection of the speaker and power cable. The latter is plugged into the five-pin socket on the side of the chassis.

amperes from the 6-volt accumulator which powers it. This is made possible partly by the introduction of 6.3-volt valves with 0.15-amp. heaters. However, this series is rather difficult to obtain, so that, if needs must, the normal 0.3-amp. tubes can be used at the expense of slightly larger battery drain.

A trouble sometimes encountered in vibrator receivers is that of "hash," or radio frequency interference set up by the vibrator itself. In sets where the vibrator power supply is built on to the same chassis as the receiver, it is sometimes quite difficult to eliminate this hash, even with the proper kind of filter in use, because of direct radiation from the vibrator to the R.F. circuits. In this set, the trouble has been minimised by keeping the power supply in a separate chassis, and with the initial model, built in our laboratory, no difficulty was experienced at all, the set remaining perfectly quiet, even at full gain.

THE CIRCUIT

A glance at the circuit shows that the set is quite conventional, and almost identical with many five-valve broadcast receivers, minus the transformer and rectifier, of course. The values of resistors are naturally different from usual, on account of the low power supply voltage of 135v., but otherwise the circuit is standard in all respects.

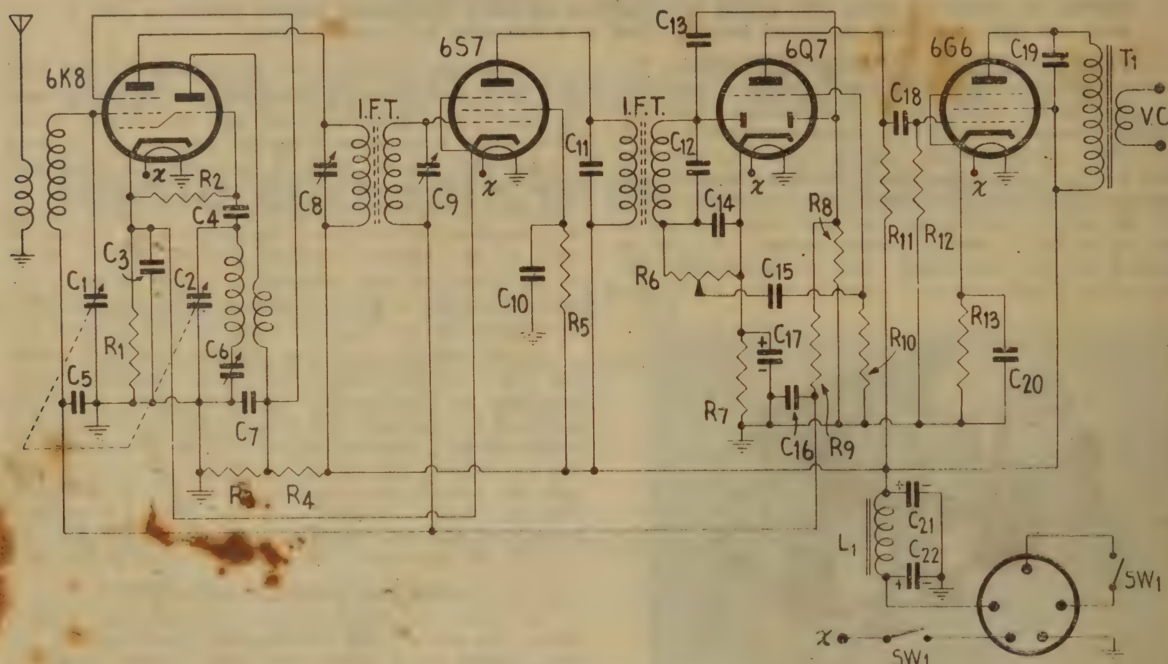
A common bias resistor, R_1 is used for the 6K8 and 6S7. A low-drain voltage divider, R_3R_4, is used to supply the oscillator plate and the screen of the 6K8, while a separate dropping resistor R_5 is used for the 6S7 screen. This is to provide a somewhat more remote cut-off for this tube, and thereby to improve the A.V.C. characteristic. The 6Q7 circuit is normal in all respects; the diode load resistor is used as the volume control, and the A.V.C. diode is returned to earth through its load resistor R_8, giving delayed A.V.C. by virtue of the voltage drop developed across R_7, the 6Q7 cathode resistor.

In the audio end no tone control has been shown, but C_{19} is really a fixed tone control condenser, serving both to prevent R.F. from straying down the loud-speaker wiring, and to limit the high-frequency response to a suitable degree. The value given in the component list can be increased or decreased to suit the conditions under which the set is operated. The size finally decided upon will depend to a large extent on the way in which the loudspeaker is installed and upon individual preference as to tone.

POWER SUPPLY CIRCUIT

To most constructors the only unusual feature about this set will be the vibrator power supply. In the original set a commercial power supply unit was used. This had the circuit shown in the power supply diagram. The five-pin socket is attached by a five-wire cable to the five-pin socket on the set, corresponding pins on the two sockets being connected together. Note that the smoothing filter is not in the power unit, but is mounted on the set chassis, where the choke and dual 10 mfd. condenser can be seen at the right-hand side in the photograph. The vibrator is of the seven-pin self-rectifying type. Both primary and secondary of the vibrator transformer are centre-tapped. One set of contacts on the vibrator reed switches the primary current first to one half of the primary and then to the other. The second set of contacts on the vibrator reed connects alternately one half and then the other of the secondary winding. In this way, the current in the secondary centre tap connection, though pulsating and therefore requiring smoothing, is in the same direction all the time, and needs no rectification. Although a built-up unit may be purchased, there is no reason, if a suitable transformer can be purchased, why constructors should not build their own vibrator power supply unit. The valves required are given in the circuit diagram, and all components should be readily obtainable. The transformer is one for a 6v. vibrator, with a secondary suitable for producing 135v. D.C. The H.T. hash filter choke L_1, in this case, can be an ordinary 10 mH. broadcast choke, but the L.T. hash filter choke L_2 will have to be home made if it cannot be purchased. It consists of 50 turns of 18-gauge enamelled wire, wound in two layers of 25 turns each on a ½in. former. Between the layers is a sheet of thin card, which is placed over the first layer,

and over which the second layer is wound. It is advisable, when the winding is completed, to soak the whole choke in melted paraffin wax. This effectively fixes the turns in place and provides a pro- tube and a four-pin socket which takes the speaker plug. Next to this, on the side of the chassis, is the five-pin socket for the power cable. The remaining components on top of the chassis are the



COMPONENT LIST

R_1 = 166 ohms (1000 and 200 in parl.).
R_2 = 50k. ½w.
R_3 = 20k. 1w.
R_4 = 2.5k. 1w.
R_5 = 70k. (100k. and 250k. in parl.).
R_6 = 0.5 Meg. Pot.
R_7 = 5k. ½w.
R_8, R_9 = 1 Meg. ½w.
R_{10} = 0.5 Meg. ½w.
R_{11} = 250k. ½w.
R_{12} = 0.5 Meg. ½w.
R_{13} = 500 ohms 1w.

C_1, C_2 = Condenser gang.
C_3, C_7 = 0.25 mfd. paper.
C_4, C_{13}, C_{14} = 0.0001 mfd. mica.
C_5, C_{10}, C_{15}, C_{18} = 0.1 mfd. paper.
C_6 = 600 mmfd. padder.
C_8, C_9, C_{11}, C_{12} = I.F. trimmers.
C_{16} = 0.01 mfd. paper.
C_{17}, C_{20} = 25 mfd. 25v. Electro.
C_{19} = 0.002 mfd. paper.
C_{21}, C_{22} = Dual 10 mfd. 450v. Electro.
L_1 = 40 ma. Vibrator Choke.
SW_1 = Double pole on/off.
T_1 = Output transformer, 10,000 ohms — v.c.

tective covering for the outside layer of wire. For those who wish to construct their own vibrator units, the under-socket connections of the seven-pin vibrator are as follows: Pins 1 and 6, transformer primary; pins 2 and 5, transformer secondary; pins 3 and 7, earth; pin 4, primary centre-tap.

CONSTRUCTION

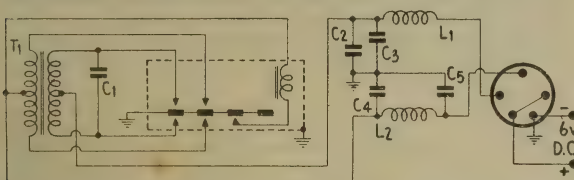
The lay-out and construction of the set can be seen very well from the photograph. The chassis is 6½in. x 10in. x 2in. In the centre front are mounted the dial and tuning condenser, with the 6K8 mounted to the right of the gang condenser. (This tube can just be seen behind the gang in the photograph.) At the right-hand side of the chassis, close to the 6K8, is the first I.F. transformer, while the 6S7 I.F. tube is in the back right-hand corner. Then, along the back of the chassis, suitably spaced are the second I.F. transformer, the 6Q7, the 6G6 output

smoothing choke and the dual electrolytic condenser. The aerial and oscillator coils are mounted under the chassis in any convenient positions, but it is well to keep them at right-angles to each other to prevent too much oscillator voltage from being induced in the aerial coil. In our case, the aerial coil was mounted on the right-hand side of the chassis a little forward of the 6K8 and the oscillator coil is mounted on the chassis midway between the 6K8 and 6S7 sockets. The only long lead induced by this lay-out is that from the 6K8 grid winding to the stator of C_1, but, since the set is at broadcast only, this is unimportant, and certainly has no effect on the lining up of the set.

CONSTRUCTION OF THE VIBRATOR UNIT

For those who wish to build their own vibrator power supply, a few words on its construction will be of assistance. It is a good plan to build the

vibrator unit into a metal box, inside which a small U-shaped sub-chassis is mounted by means of rubber washers. This shock-mounting prevents the vibrator from giving forth mechanical humming noise when the unit is screwed down to a cabinet or other piece of wood which might act as a sounding board. The box can be 6½in. x 4in. x 6in. high, the bottom being made removable, as though it were a lid. The inside chassis would be 6in. x 3½in. x 2in. deep, made in the form of a U with no sides. The ends, 3½in. x 2in., have a 1in. flange turned inwards underneath, and in the centre of these flanges are the holes by which the chassis is mounted on the bottom of the enclosing box. In one end of the chassis is the five-pin socket for the power cable, and a ⅜in. hole through which are taken the heavy leads from the battery. On the top of the chassis are mounted the vibrator socket and the transformer. The hash filter chokes and condensers are wired in under the chassis in the usual way. The outside box should have clearance holes for the power-lead plug and battery cable, so that these do not touch it.



Circuit and component valves for the vibrator power supply unit.

T_1 = 6v. vibrator transformer, centre-tapped primary, output 135v. D.C.
C_1 = 0.05 mfd. 500v. mica.
C_2, C_4, C_5 = 0.1 mfd.
C_3 = 0.001 mfd. mica.
L_1 = 10 mfd. R.F. choke.
L_2 = R.F. choke (see text).

SWITCHING ARRANGEMENT

The on/off switch, SW_1, is mounted on the front panel of the set, on the left-hand side, directly in front of the speaker socket. It can be any double-pole switch with low-resistance contacts. Tracing through the wiring of the power sockets on both set and power supply, it will be seen that the section connected to pin 1 switches on the tube heaters, and the other, connected to pins 3 and 4, switches on the 6v. to the vibrator. Thus, as long as the switch is in the "off" position, there is no danger in plugging the power cord into the units in any order, since, until the set switch is on, the plugs carry 6v. D.C. only.

ALIGNMENT

The set is intended to use a 465 kc/sec. I.F. and standard unshielded coils and condenser gang. The aerial and oscillator trimmers are not shown on the circuit diagram, as they are part of the gang condenser itself. Alignment of the set is carried out similarly to the "Radel 5," to which reference can be made if necessary. The padder should be adjusted at 600 kc/sec., or on 2YA if a signal generator is not available, and the trimmers peaked up at 1450 kc/sec., or on 3ZB or some nearby station.

It should be remembered that most new I.F. transformers are adjusted approximately before leaving the factory, so that the settings of these should be left alone during the initial adjustment. If necessary, they can be peaked up after the trimmers and padders have been adjusted.

ALTERNATIVE TUBE TYPES

If types 6S7 and 6G6 tubes are not available, types 6K7 and 6V6 may be used at the expense of higher battery drain and somewhat higher H.T. current. The 6K7 draws an extra 5 ma. compared with the 6S7, so that a slight reduction in the common bias resistor R_1 will need to be made. A suitable value would be 125 ohms, and can be made from two 25-ohm ½-watt resistors in parallel.

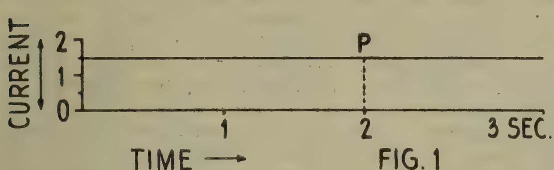
The 6V6, with 135 volts on plate and screen, will draw approximately 20 ma. as against 14 ma. for the 6G6, so that the vibrator transformer will have to be capable of supplying an extra 11 ma. altogether, taking both replacements into consideration. The 6V6, however, will provide almost twice the power output of the 6G6, so that one is amply repaid for the extra current drawn. The cathode resistor R_{13} should have a value of 250 ohms if the 6V6 is used, and the output transformer should match 7000 ohms to the voice coil instead of 10,000 ohms for the 6G6. With these modifications, the alternative tubes will be quite satisfactory.

Power Supply From The Mains

Most beginners and experimenters reach a stage where they would like to use indirectly heated valves of the type used in standard receivers in order to take advantage of their greater gain compared with battery tubes, and to do away with the nuisance of dry batteries. This article gives a brief description of how A.C. operated power supplies work, and describes a good circuit from which to power small sets up to three or four valves.

WHY USE A.C. VALVES?

Well, in the first place, they give much more gain than their battery counterparts, so that much better performance can be obtained from one valve (and larger) regenerative sets so useful to the home builder. Secondly, since A.C. valves are indirectly heated, having a cathode and heater instead of a filament, more and better circuits can be used with them than with battery valves. Next, the small size and self-shielding of the metal tubes make for much better set layouts, and make possible excellent performance at much shorter wavelengths than can be successfully covered using even the more modern battery types. In short, using indirectly heated metal tubes opens out a whole new field before the experimenter, without even starting to think of such things as superheterodynes, or advanced receivers generally.



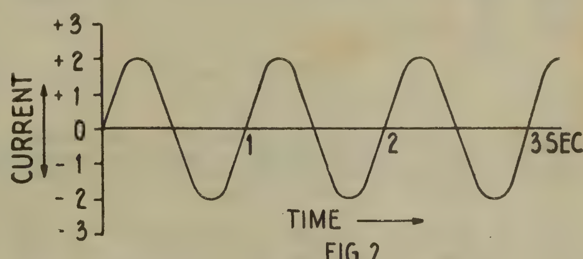
This figure gives a graphical representation of a direct current and its behaviour with respect to time.

WHAT IS A.C.?

Before going on to describe a power supply worked from the mains, it is very important to give some idea of what alternating current is, since without some ideas on this subject the builder is liable to encounter a good many snags. It is well known, of course, that a battery produces direct current, or D.C. for short. This simply means that, in any circuit powered by a battery, the current can flow in only one direction—from the positive terminal of the battery through the external circuit to the negative terminal.

Alternating current is so called because it flows, not in one direction along a wire, but alternately backwards and forwards. Thus, a source of alternating current, such as the two terminals of an electric lamp socket, cannot be said to have one positive and one negative terminal, because each becomes positive or negative at the rate at which the reversals of current occur. The easiest way to describe this behaviour on the part of an alternating current source, such as an alternator (A.C. generator), is by means of a graph. No doubt many readers of this article have had little to do with these useful devices, but a start must be made some time, and when the idea of a graph has been grasped, its extreme usefulness will be readily seen.

Figs. 1 and 2 are graphs showing respectively the behaviour of direct and alternating currents with regard to time. The introduction of the time factor into our thinking about electric currents is the only new idea presented, but is made quite clear by the figures. The horizontal and vertical lines are called the **axes** of the graph in each case, and their intersection is called the **origin.** Along the vertical axis we represent current, and time is measured along the horizontal axis, the value at the origin in each case being zero. Between the axes we have a line representing in these cases how **current** changes as time goes on. The only thing which may cause difficulty to some is seeing how any particular time can be given for a value of 0 (nought). However, this is quite easy, for the time 0 (at the origin) simply



Here is illustrated the behaviour of an alternating current with respect to time. Note that the value of current is changing constantly, and flows first in one direction and then in the other along the wire carrying it.

represents the time at which we start measuring, and can be any particular moment we choose. The time axis is marked off in seconds. Thus, the time at the origin could be 12 noon, or midnight, or breakfast time, or any time at all, but this is quite unimportant, because all that we are interested in is what happens 1, 2, 3, etc., seconds after any time we like to think of.

First, let us consider Fig. 1, which represents the behaviour of a direct current with respect to time. It will be noticed that the vertical axis has been marked off in amperes, the unit of current, just as the time axis has been marked off in seconds. The graph therefore represents a current of 1.5 amperes D.C. If we take, say, two seconds after the start of the measurement of current and erect a line perpendicular to the time axis, this cuts the graph at P. If now we proceed horizontally from P to the current axis, this will give us the value of current at the time of 2 seconds. In this case it is 1.5 amperes. If we do the same thing at, say, 3 seconds, we find the current is still 1.5 amps. Thus, the graph tells us that at all times the value of current is the same, namely, 1.5 amps. This is a graphical demonstration of what is meant by a direct current. A direct current of 1 amp. would be represented on

the graph by a line parallel to the time axis, cutting the current axis at the 1-amp. mark.

Now, considering Fig. 2, one important difference can be seen. The current axis has been extended on both sides of the time axis, and we have introduced the term plus and minus to represent the top and bottom halves of the current axis. This procedure allows us to introduce on the graph the idea that current can flow in a wire in either of two directions. Suppose we have a wire laid parallel to the lines of this page. We could call a current flowing from left to right **positive**, and a current flowing from right to left would then have to be called **negative**.

The first thing which will be noticed about the graph of Fig. 2 is that part of the time the current is shown as above the time axis, and therefore as flowing from left to right in our imaginary wire, while the rest of the time it is flowing from right to left and is therefore shown below the time axis.

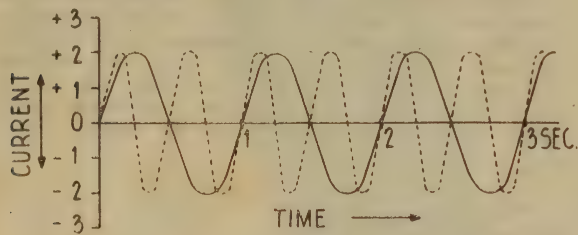


FIG 3

Here we have two alternating currents, identical in all respects, except for frequency. The dotted one has twice the frequency of the solid one, since two complete cycles of the first take place during one cycle of the latter.

It can be seen, too, that at certain times the current is zero and that at all times the value of the current is changing. In Fig. 2, for instance, we have drawn a graph which represents a current that reaches a maximum value of 2 amperes in one direction decreases, passes through zero, and builds up to a maximum value of 2 amperes in the opposite direction. This is an exact description of just how an alternating current behaves.

Fig. 2 also explains the meaning of the term **frequency**, often found in dealing with alternating currents. At the starting time, marked zero, the current also is zero. A half-second afterwards the current passes through zero again, while one whole second after the start the current passes through zero a third time. Thus, between zero time and 1 second, the current has passed through its positive maximum, zero, and its negative maximum, and has reached zero again. If now we trace what happens between one and two seconds after the start we find that the whole process is repeated, and so on for as long as we like to continue the graph. The part between 0 and 1 second is called one **cycle**. Therefore, the part between 1 and 2 seconds is also one cycle. We can say, therefore, that the alternations take place at a rate of one cycle a second, or that the **frequency** of the current is one cycle a second. Fig. 3 shows two alternating currents drawn on the same graph. Each reaches the same maximum value of 2 amps. in each direction, but one goes through two complete cycles every second. Its frequency is therefore two cycles a second.

This rather long description should have given a clear enough idea of the nature of an alternating current for us to proceed to the question of how we can produce from it a direct current, suitable for supplying to the plates of valves, as a substitute for batteries.

RECTIFICATION.

The device used for changing A.C. into D.C. is known as a rectifier, and may be—in fact, usually is—a valve. The type used for this purpose is the

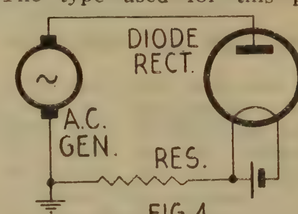


FIG. 4

Circuit showing how a diode valve is used to rectify an alternating current supplied by a generator. It does this by conducting current in one direction only, as illustrated in Fig. 5.

simplest of all valves, the diode. It is well known that a diode will pass current only in one direction. For instance, once the filament is heated, if we connect a battery between plate and filament, we find that if the positive terminal of the battery is connected to the plate, a current will flow through the valve just as if it were a piece of wire. However, if the negative terminal of the battery is connected to the plate, no current flows at all. Thus, the valve can be regarded as a gadget which can be wired into a circuit and will allow current to flow in one direction only.

Fig. 4 shows a simple circuit consisting of an A.C. source, such as the mains, a diode in series with a resistor having been placed across the terminals. It is at this point that we can fully realise the usefulness of our graphs, for a new one, Fig. 5, enables us to visualise exactly what happens in this circuit.

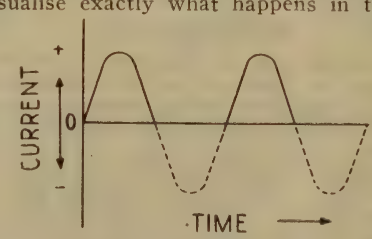


FIG. 5

In Fig. 5 the negative half of the current "wave" is shown dotted. Since the diode can conduct only when the plate is positive, the upper half of Fig. 5 shows the way in which current flows through the diode. When the current swings in the negative direction no current passes through the circuit, so that for half the time current flows and for the other half there is no current. These pulses of current do not look very much like our picture of direct current shown in Fig. 1, but, for all that, the current now flows only in one direction. It is possible by means of a smoothing circuit to eliminate the ripple, as it is called, from the output of the diode, so that we end up with a current which is both unidirectional and constant in value, and is as nearly as we please equivalent to the current delivered by a battery. Just

how the smoothing circuit works will have to be left for another article, but its construction is very simple.

The type of rectification given by a single diode is called half-wave rectification, because one-half of the current wave is completely lost. The practical ciruit in Fig. 6 uses a double diode, each half of which performs half-wave rectification, in such a way that the half-waves cut off by one diode are used by the other, so that the output of the two is as in Fig. 7. This circuit is called a full-wave rectifier, and, as can be seen, acts to reverse the negative half of the wave instead of cutting it off altogether.

Comparing Fig. 7 with the upper half of Fig. 6, it can be seen that the output of the full-wave rectifier, though still not constant, is much more so than that of the half-wave type. For this reason, it is easier to smooth, which is why practically all sets and amplifiers use the full-wave circuit.

PRACTICAL DETAILS.

In Fig. 6 we have a power transformer. This is because the mains give us 230 volts, and the voltages we require are both higher and lower than this. For the heaters of the valves, we require 6.3 volts A.C., which is derived from this winding on the transformer and fed straight to the valve without rectification. For the high voltage supply we require a winding which has a tap at the centre. The tap is earthed, and each half of the H.T. winding gives us 320 volts A.C. Each end of this winding goes to one of the plates of the double diode rectifier. In our circuit the latter type is a type 6X5-G, which itself has a heater and a cathode. The rectified A.C. is taken from the cathode and fed through the smoothing filter, after which the irregularities will be absent, giving us a high D.C. voltage comparable to that of a bank of batteries. The tapped resistor across the output of the filter is known as a bleeder resistance and is used to prevent damage to the power supply should it be turned on with no other load connected to it. The bleeder also acts as a voltage divider, for it is the type of resistor that has adjustable bands which may be set to give any voltage from 0 to the maximum provided by the power supply. On the circuit we have shown three taps which are set to give 250 volts, 100 volts, and 45 volts respectively. These values are chosen because all the valves liable to be used in small receivers have a maximum plate voltage of 250, require a screen voltage of 100, and if triodes are used as a regenerative detector, 45 volts. The condensers from the taps to earth should not be omitted since they prevent a type of instability that does not occur when batteries are used.

The layout of parts is not very important, but the supply should be built on a metal chassis. It is very important not to connect the electrolytic smoothing condensers the wrong way round, since this ruins them in about five seconds. The positive end is indicated in the tubular types by red paint, while with the can types, the insulated centre conductor is the positive terminal.

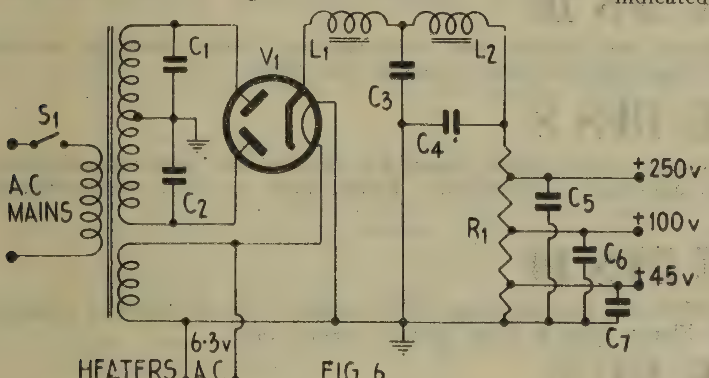


FIG 6

C_1, C_2 = 0.0001 mfd. mica. 600 volts.
C_3, C_4 = 8 mfd. electrolytic.
C_5, C_6, C_7 = 1 mfd. 600v. paper.
R_1 = 25k. 25 watts, with three sliders.
L_1, L_2 = 40 ma. vibrator type chokes.
V_1 = 6X5-G or GT.
Transformer = 320v.-a-side.
S_1 = on/off switch.

Note: The negative terminals of C_3 and C_4 are earthed.

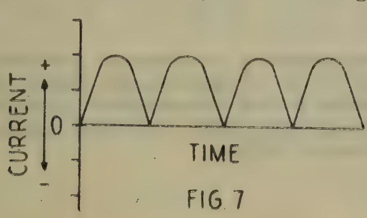


FIG 7

This figure shows how two diodes in what is known as a full wave rectifier circuit make use of both halves of the A.C. cycle in producing a current that flows in one direction only.

The 40 ma. vibrator chokes in the filter have been specified, because they are small and inexpensive, and quite satisfactory as long as the total current taken from the power supply does not exceed their rating, which will be the case as long as a power tube is not used and only headphone operation is required.

PRECAUTIONS TO BE TAKEN.

A few words of warning are necessary to those building A.C.-operated equipment for the first time. The voltages inside the power supply are high enough to be dangerous. NEVER under any circumstances touch the inside when it is switched on. NEVER connect or disconnect the plug to the set when the power is on. NEVER adjust the voltage divider tappings with the power switched on.

TUBE DATA

Our Tube Data this month takes the form of two pages of tabulated information on the operation of triode and pentode power tubes. Some of this information is to be found in the usual valve handbooks, but much of it is new.

For example, under the triode heading are given operating data for many of the commoner pentodes and beam tetrodes connected as triodes. In addition, power operation is given for many small pentodes and triodes not normally considered as power tubes at all. For instance, it is interesting to note that a 6J7, pentode connected, with the appropriate load impedance, can deliver over half a watt of power.

These tables will be of considerable use to designers of equipment, who wish to make use of available tubes or to cut down the number of tube types in a design.

Type	Plate Volts	Screen Volts	Peak A-F Grid Volts	Fixed Bias Volts	Bias Resistor Ohms	† Plate Current mA	† Screen Current mA	Plate Load Imp. Ohms	Power Output Watts
POWER TRIODES—SINGLE VALVE CLASS A₁									
3S4*‡	67.5	—	7.5	—	1,000	7.4	—	3,500	0.058
1L5-G*	135	—	6.25	—	1,280	4.4-4.7	—	12,000	0.105
6J7-G*	250	—	8.0	—	1,230	6.5	—	22,000	0.275
6B8-G*	250	—	20	—	2,500	8.0	—	20,000	0.35
6F6-G*	250	—	20	—	650	31-32	—	4,000	0.8
6V6-GT / 6V6-G *	250	—	15	—	400	37.5	—	3,500	1.0
45	250	—	50	—	1,470	34	—	3,900	1.6
6L6-G / 807 *	250	—	20	—	400	47-50	—	3,000	1.6
6V6-GT / 6V6-G *	300	—	20	—	513	39	—	4,800	1.65
45	275	—	56	—	1,550	36	—	4,600	2.0
6L6-G / 807 *	300	—	25	—	446	54-56	—	4,500	2.2
2 type 45 in parallel	250	—	50	—	735	68	—	2,000	3.2
6L6-G / 807 *	350	—	30	—	472	61-63.5	—	4,500	3.3
2A3	250	—	45	—	750	60	—	2,500	3.5
2 type 45 in parallel	275	—	56	—	775	72	—	2,300	4.0
POWER TRIODES—PUSH-PULL CLASS A₁									
6F6-G*	250	—	40 (g-g)	—	325	62 (total)	—	8,000 (p-p)	1.6
6V6-GT / 6V6-G *	250	—	30 (g-g)	—	200	75 (total)	—	7,000 (p-p)	2.0
6L6-G / 807 *	250	—	40 (g-g)	—	200	94 (total)	—	6,000 (p-p)	3.2
45	250	—	100 (g-g)	—	735	68 (total)	—	7,800 (p-p)	3.2
6V6-GT / 6V6-G *	300	—	40 (g-g)	—	256	78 (total)	—	9,600 (p-p)	3.3
45	275	—	112 (g-g)	—	775	72 (total)	—	9,200 (p-p)	4.0
6L6-G / 807 *	300	—	50 (g-g)	—	223	108 (total)	—	9,000 (p-p)	4.4
6V6-GT / 6V6-G *	300	—	50 (g-g)	−25	—	42 (total)	—	6,000 (p-p)	4.75
4 type 45 push-pull parallel	250	—	100 (g-g)	—	370	136 (total)	—	3,900 (p-p)	6.4
6L6-G / 807 *	350	—	60 (g-g)	—	236	122 (total)	—	9,000 (p-p)	6.6
2A3	250	—	90 (g-g)	—	375	120 (total)	—	5,000 (p-p)	7.0
4 type 45 push-pull parallel	275	—	112 (g-g)	—	390	144 (total)	—	4,600 (p-p)	8.0
807*	400	—	75 (g-g)	—	310	116 (total)	—	12,000 (p-p)	8.4
BEAM POWER TETRODES AND PENTODES—SINGLE VALVE CLASS A₁									
1D8-GT (Pentode Section)	45	45	4.5	—	2,370	1.6	0.3	20,000	0.035
	67.5	67.5	6.0	—	1,300	3.8	0.8	16,000	0.1
1L5-G	90	90	2.75	—	555	3.6	0.9-1.5	25,000	0.12
1Q5-GT	83.5	83.5	6.5	—	1,200	5.0	0.5	15,000	0.14
3S4‡	67.5	67.5	7.0	—	805	7,2	1.5	5,000	0.18
1D8-GT (Pentode Section)	90	90	9.0	—	1,500	5.0	1.0	12,000	0.2
1Q5-GT	85	85	5.0	—	640	7.0	0.8	9,000	0.25
3V4‡	85	85	5.0	—	595	6.9	1.5	10,000	0.25
1Q5-GT	90	90	4.5	—	416	9.5	1.3	8,000	0.27
3S4‡	90	67.5	7.0	—	795	7.4	1.4	8,000	0.27
3V4‡	90	90	4.5	—	390	9.5	2.1	10,000	0.27
6B8-G	200	100	5.0	—	970	3.8-4.1	1.0-1.1	39,000	0.31
1L5-G	135	135	4.75	—	600	6-6.4	1.5-2.4	15,000	0.34
6J7-G	250	100	2.5	—	600	2.8-3.3	0.7-0.9	56,000	0.38
6B8-G	250	125	6.25	—	940	5.3-5.6	1.4-1.5	35,000	0.54
6J7-G	250	175	4.0	—	440	7.3	1.8	25,000	0.65
6B8-G	250	150	7.5	—	850	7.0-7.4	1.9-2.0	25,000	0.67
1L5-G	180	180	6.25	—	508	9.5-9.7	2.3-4.0	15,000	0.75
6V6-GT / 6V6-G	250	100	5.0	—	250	17.5-18.4	0.7-1.3	14,000	1.5
	180	180	8.5	—	250	29-30	3.0-4.0	5,500	2.0
6F6-G	250	250	16.5	—	410	34-35	6.5-9.7	7,000	3.1
	285	285	20.0	—	440	38-38	7.0-12	7,000	4.5
6V6-GT	250	250	12.5	—	232	45-47	4.5-7.0	5,000	4.5
	315	225	13.0	—	317	34-35	2 2-6.0	8,500	5.5
6L6-G / 807	250	250	14.0	—	170	75-78	5.4-7.4	2,500	6.5
	275	275	15.4	—	162	86-90	6.2-8.3	2,380	8.25
807	375	250	15.6	—	200	71-76	4.2-6.4	4,000	11.3
807	385	275	19.8	−19.8	—	62-76	2.9-8.1	4,000	13.7

* triode connected; ‡ filament in parallel arrangement, † two figures indicate zero signal and max. signal currents. One figure is zero signal current.

Type	Plate Volts	Screen Volts	Peak A-F Grid Volts	Fixed Bias Volts	Bias Resistor Ohms	† Plate Current mA	† Screen Current mA	Plate Load Imp. Ohms	Power Output Watts
BEAM POWER TETRODES AND PENTODES—PUSH-PULL CLASS A_1									
6F6-G	250	250	33 (g-g)	—	205	68-70 (total)	13-19.4 (total)	14,000 (p-p)	6.2
6F6-G	285	285	40 (g-g)	—	220	76-76 (total)	14-24 (total)	14,000 (p-p)	9.0
6V6-GT / 6V6-G	250	250	25 (g-g)	—	116	90-94 (total)	9-14 (total)	10,000 (p-p)	9.0
6V6-GT / 6V6-G	250	250	30 (g-g)	−15	—	70-79 (total)	5-13 (total)	10,000 (p-p)	10.0
6F6-G	315	285	58 (g-g)	—	320	62-73 (total)	12-18 (total)	10,000 (p-p)	10.5
6F6-G	315	285	48 (g-g)	−24	—	62-80 (total)	12-19.5 (total)	10,000 (p-p)	11.0
6V6-GT / 6V6-G	315	225	26 (g-g)	—	158	68-70 (total)	4.4-12 (total)	17,000 (p-p)	11.0
6L6-G / 807	250	250	35.6 (g-g)	—	125	120-130 (total)	10-15 (total)	5,000 (p-p)	13.8
6L6-G / 807	250	250	32 (g-g)	−16	—	120-140 (total)	10-16 (total)	5,000 (p-p)	14.5
4 type 6V6-GT push-pull parallel	250	250	25 (g-g)	—	58	180-188 (total)	18-28 (total)	5,000 (p-p)	18.0
6L6-G / 807	270	270	40	—	125	134-145 (total)	11-17 (total)	5,000 (p-p)	18.5
4 type 6V6-GT push-pull parallel	315	225	26 (g-g)	—	79	136-140 (total)	8.8-24 (total)	8,500 (p-p)	22.0
6L6-G / 807	300	300	39 (g-g)	−19.5	—	157-182 (total)	12.9-20 (total)	4,750 (p-p)	22.8
6L6-G / 807	300	300	44.5 (g-g)	—	119	157-170 (total)	12.9-20 (total)	4,750 (p-p)	24.0
BEAM POWER TETRODES AND PENTODES—PUSH-PULL CLASS AB_1									
6V6-GT / 6V6-G	250	250	30 (g-g)	—	163	70-79 (total)	5-13 (total)	10,000 (p-p)	10
6V6-GT / 6V6-G	315	250	30 (g-g)	—	194	76.5-70 (total)	4.9-10.5 (total)	12,000 (p-p)	13
6V6-GT / 6V6-G	285	285	38 (g-g)	—	180	70-92 (total)	4-13.5 (total)	8,000 (p-p)	14
6L6-G / 807	360	270	45 (g-g)	−22.5	—	88-140 (total)	5-11 (total)	3,800 (p-p)	18
807	400	250	43.8 (g-g)	—	190	96-110 (total)	4.6-10.8 (total)	8,500 (p-p)	24
6L6-G / 807	360	270	57 (g-g)	—	250	88-100 (total)	5-17 (total)	9,000 (p-p)	24.5
6L6-G / 807	360	270	45 (g-g)	−22.5	—	88-140 (total)	5-11 (total)	6,600 (p-p)	26.5
807	400	300	57 (g-g)	—	200	112-128 (total)	7-16 (total)	6,600 (p-p)	32
807	400	300	50 (g-g)	−25	—	102-152 (total)	6-17 (total)	6,600 (p-p)	34
807	500	300	50 (g-g)	−25	—	102-156 (total)	6-17 (total)	8,600 (p-p)	44
807	600	300	55 (g-g)	−27.5	—	80-149 (total)	4.7-16.5 (total)	10,600 (p-p)	54
BEAM POWER TETRODES AND PENTODES—PUSH-PULL CLASS AB_2									
6F6-G	375	250	82 (g-g)	−26	—	34-82 (total)	5-19.5 (total)	10,000 (p-p)	18.5
6F6-G	375	250	94 (g-g)	—	340	54-77 (total)	8-18 (total)	10,000 (p-p)	19.0
6L6-G (Peak grid input power 0.14W. approx.)	360	225	52 (g-g)	−18	—	78-142 (total)	3.5-11 (total)	6,000 (p-p)	31.0
6L6-G (Peak grid input power 0.27W. approx.)	360	270	72 (g-g)	−22.5	—	88-205 (total)	5-16 (total)	3,800 (p-p)	47.0
807	400	300	78 (g-g)	−25	—	102-240 (total)	5-10 (total)	3,200 (p-p)	55.0
807 (Peak grid input power 0.2W. approx.)	500	300	78 (g-g)	−25	—	102-240 (total)	5-10 (total)	4,240 (p-p)	75.0
807 (Peak grid input power 0.1W. approx.)	600	300	78 (g-g)	−30	—	80-200 (total)	5-10 (total)	6,400 (p-p)	80.0
807 (I.C.A.S.) (Peak grid input power 0.2W. approx.)	750	300	92 (g-g)	−32	—	60-240 (total)	5-10 (total)	6,950 (p-p)	120.0

PUSH PULL CLASS "B" FOR BATTERY RECEIVERS

Type	Plate Voltage	Grid Bias	Zero Sig. Plate Current mA	Max. Sig. Plate Current mA	Max. Sig. Driving Power Watts (Approx.)	Plate Load Imp. Ohms	Power Output Watts
1J6 / 19 (twin triode)	135	−4.5	1.4	13.8	0.038	20,000	1.0
	135	−4.5	1.4	18.0	0.09	15,000	1.25
	135	−4.5	1.4	24.5	0.12	10,000	1.6
	135	0	10.0	—	0.17	10,000	2.1
1H4-G / 30 (single triode)	157.5	−15	1.0	—	0.26	8,000	2.1

POWER TRIODES—PUSH-PULL CLASS A_1

A suitable set of operating conditions for push-pull class A_1 operation of any of the power triodes listed above can be found as follows:

(a) Plate Voltage: as stated.
(b) Plate Current: multiply current given by 2.
(c) Peak A-F Grid Volts: multiply voltage given by 2. (This is the grid-to-grid value.)
(d) Bias Resistor: divide resistance given by 2.
(e) Plate Load Impedance: multiply resistance by 2.
(f) Power Output: multiply power by 2.

As an example take the conditions shown for type 2A3, and find the conditions for Class A_1 push-pull operation.

(a) Plate Voltage: 250.
(b) Plate Current: 60 × 2 = 120 mA.
(c) Peak A-F Grid Volts: 45 × 2 = 90 volts (grid-to-grid).
(d) Bias Resistor: 750 ÷ 2 = 375 ohms.
(e) Plate Load Resistance: 2,500 × 2 = 5,000 ohms (plate-to-plate).
(f) Power Output: 3.5 × 2 = 7 watts.

BEAM POWER TETRODES AND PENTODES—PUSH-PULL CLASS A_1

The conditions for push-pull class A_1 operation can be found from the list given. The procedure is exactly the same as for the triodes, but in addition the screen current must also be multiplied by 2.

As an example take the type 6V6-GT.

(a) Plate Voltage and Screen Voltage: 250V.
(b) Plate Current: 45 × 2 = 90 mA.
(c) Peak A-F Grid Volts: 12.5 × 2 = 25 volts (grid-to-grid).
(d) Bias Resistor: 232 ÷ 2 = 116 ohms.
(e) Plate Load Resistance: 5,000 × 2 = 10,000 ohms (plate-to-plate).
(f) Power Output: 4.5 × 2 = 9 watts.
(g) Screen Current: 4.5 × 2 = 9 mA.

Other operating conditions can, of course, be found and these may be more suitable for a particular application. The above methods will serve as a guide when the required information for Class A_1 push-pull operation is not available.

BRITISH I.R.E. FORMS NEW ZEALAND BRANCH

A New Zealand section of the British Institution of Radio Engineers is now in process of formation, and it is felt that some information on the Institution will be of interest to New Zealand engineers and technicians.

The British I.R.E. was founded in 1925 and incorporated in 1932. Its founders were engineers and scientists prominent in Great Britain, whose insistance from the start was upon the maintenance of very high standards for membership. Their motto was "quality before quantity." As a result, membership in earlier years was not large, and the Institution did not become well-known outside Great Britain. The long-term policy of the Institution's founders has now borne its fruit, and the Institution, with a present membership of 3,600, of whom about 3,300 are normally resident in Great Britain, has established itself as the premier body catering for the needs of British Radio Engineers. It is so recognised by the British Government, upon whose Parliamentary and Scientific Committee the Institution is represented. It is also represented on the City and Guilds of London Institution, the British Standards Institute, and the British Radio Trades Examination Board, for which the British I.R.E. acts as examining body.

The Institution holds its own graduateship examinations, in which it maintains a standard as high as that required for any similar professional body in the world. Its standards for corporate membership are of a degree which ensures that only a fully-qualified person can obtain admission. It is hoped that facilities can be arranged in due course for New Zealand aspirants to membership to sit its examinations in this country.

Past Presidents, Vice-Presidents and Executive Council of the Institution have included Great Britain's leading engineers. The President of the Institution for 1946/47 is Admiral Lord Louis Mountbatten, K.G., C.B., G.C.V.O., D.S.O., A.D.C., R.N.—well known to the public as a sailor-warrior, but known equally to his fellow engineers as a radio engineer by training and inclination.

The Institution has set up a Charter Committee and is working toward the day when it hopes that the Royal Charter will be granted it.

In New Zealand, the local Section intends to press its claims for Governmental recognition. The highest technical qualification obtainable in New Zealand by Governmental examination is the Technical Certificate in Broadcasting. Between this and a B.E. in Electronics, provision for which exists now at Canterbury College, there is an unduly and unfairly wide gap. This gap the Brit. I.R.E. will seek to fill to some degree.

The Institution publishes a Journal which is sent to members of all grades, and in which papers appear contributed by the membership. Many well-known names in radio appear as authors in the Journal.

Any engineer, or prospective engineer, interested in allying himself with the British I.R.E. in any of its grades from Student to full Member, is invited to communicate with either Mr. W. J. Blackwell, M. Brit. I.R.E., P.O. Box 38, Auckland, or Mr. W. A. Penton, A.M. Brit. I.R.E., C/o Dominion Physical Laboratory, Lower Hutt, for further information.

THE SERVICE SECTION

PRACTICAL TROUBLE-SHOOTING—Part 2

By C. R. LESLIE, late Technical Officer, Royal Aircraft Establishment.

SYSTEM IN PRACTICAL PROCEDURE

The question as to what is the best method for dealing with trouble detection is rather a controversial one, and it is with some diffidence that we enter upon it. There are some who prefer signal tracing by a "signal substitution" method, while others favour a straight-out "point-to-point" voltage, current, and resistance test method. The problems that arise in servicing are so diverse in nature that it would not be advisable to limit oneself to a single definite course of action, and one must be guided very largely by the immediate circumstances. But it can be said with safety that it is wise to become conversant with both methods, as they are somewhat inter-related. Perhaps we should first differentiate between the two.

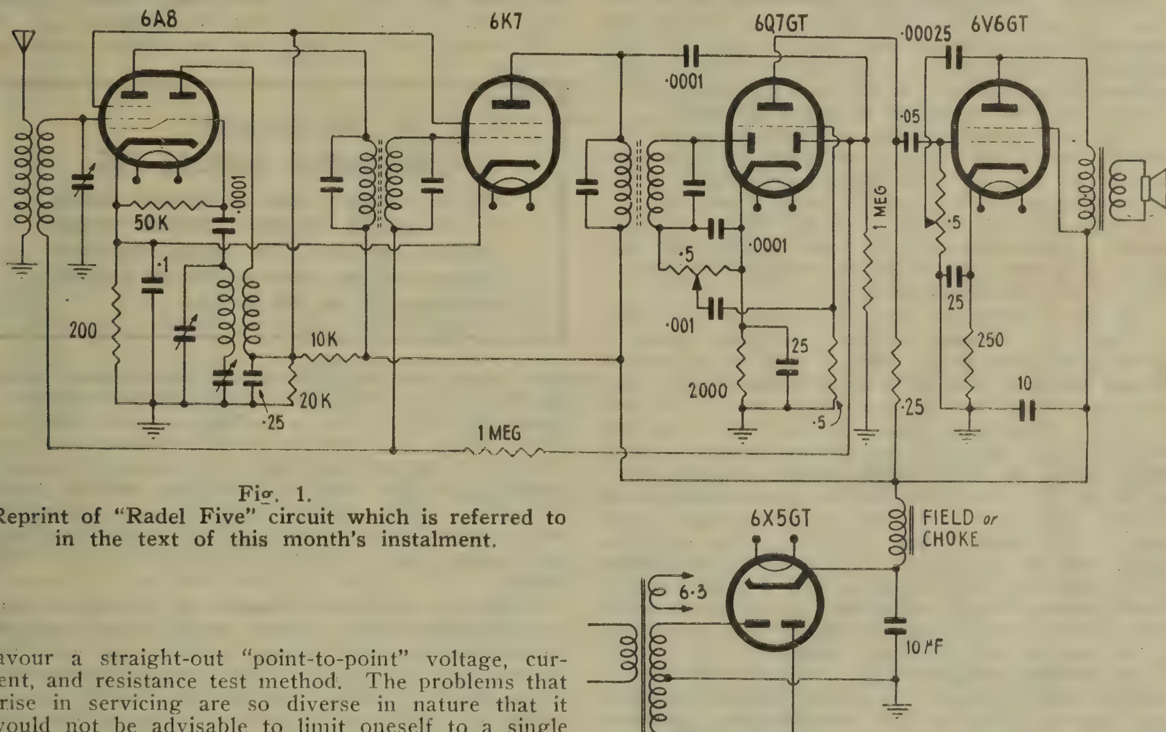


Fig. 1.
Reprint of "Radel Five" circuit which is referred to in the text of this month's instalment.

The signal substitution method divides a receiver into two main sections, namely, an audio section and an R.F. section. If the output of an audio frequency signal generator be injected into the input of the whole audio section, the signal should be heard from the reproducer, i.e., the loudspeaker or phones, if all is well. If not, the audio signal can be injected successively into the input and output terminals of each stage until the signal is heard—the faulty stage will then be the one immediately before. Alternatively, we could work backwards from the speaker in the same manner until we found the unresponsive point. The faulty stage is then examined in detail with regard to voltages and currents, and the quality of the components, until the faulty unit is located. Similarly, the R.F. section is checked with an R.F. signal generator by injecting the signal at the input and output points of each stage, starting with the last, and working back towards the aerial. On locating a no-signal stage, it is examined in detail as above.

In the point-to-point system, checks are made on all the voltages, from the supply to the first valve, at each of the main points or electrodes. Results are compared with manufacturer's data, and where any wide discrepancy is found, then that stage is carefully examined for currents and quality of components as above. Signals may be injected to study the electrical behaviour of certain components under operating conditions.

An advantage of the latter system is that only the multi-range test meter is required, which is a convenience when making tests at the customer's house on account of the compactness of the equipment. In quite a number of cases we shall have a pretty shrewd idea of the probable trouble and at what stage it is occurring, from the symptoms experienced, and naturally, therefore, we shall start digging in that locality without more ado. This is partly why we stressed the importance of questioning the owner, in our previous article, and of getting him to talk freely about the set, its history, and behaviour.

For instance, suppose he complains that when he

taps the set or the volume control or other knob, the set starts up a buzzing sound, perhaps just while the jarring is occurring or perhaps persisting for several seconds. Obviously, this is a mechanical defect, and it will not help us to solve it by taking point-to-point voltage readings. We would normally attempt to localise the stage by tapping various parts just hard enough to set the symptoms going. Then, as we got "hotter" upon the trail the taps would require less intensity. On deciding on the stage, we would first make a valve change, as this might cure the trouble; if not, we would try changing the valves at adjacent stages each side, in case our localising had not been quite correct. The probability is that a valve has a loose connection internally, but if this is not the answer we must turn to the wiring and components and look for dry or improperly-soldered connections, and perhaps apply discreet taps on the components themselves. In this way the nigger in the woodpile will be unearthed in a few minutes.

The two main methods are used when the receiver is "dead" and history and cause are unknown, so that we have to start from scratch as it were. Let us consider such a case in some detail, and see how both methods can be used to remedy matters. Speed of fault-location is the main thing to aim for, and we will leave the reader to decide which system will suit his circumstances best.

As a hypothetical case, we may assume that a "Radel A.C. Broadcast Five" (see July issue of "Radio and Electronics," 1946) is laid before us in a defunct state and it is up to us to resuscitate it. The first thing NOT to do is to plug the set in and try it out, because we know it won't work and we don't know the reason; it may be that there is a short circuit across the H.T. supply somewhere, and turning on the juice may burn out the mains transformer or blow the rectifier (if this has not already been done!). Of course, there MAY not be anything wrong with the set; it may have been the installation at the house that was to blame, such as a blown fuse, a faulty mains supply point, open circuit in the aerial lead, or a short between the aerial and earth—but at the moment we just don't know.

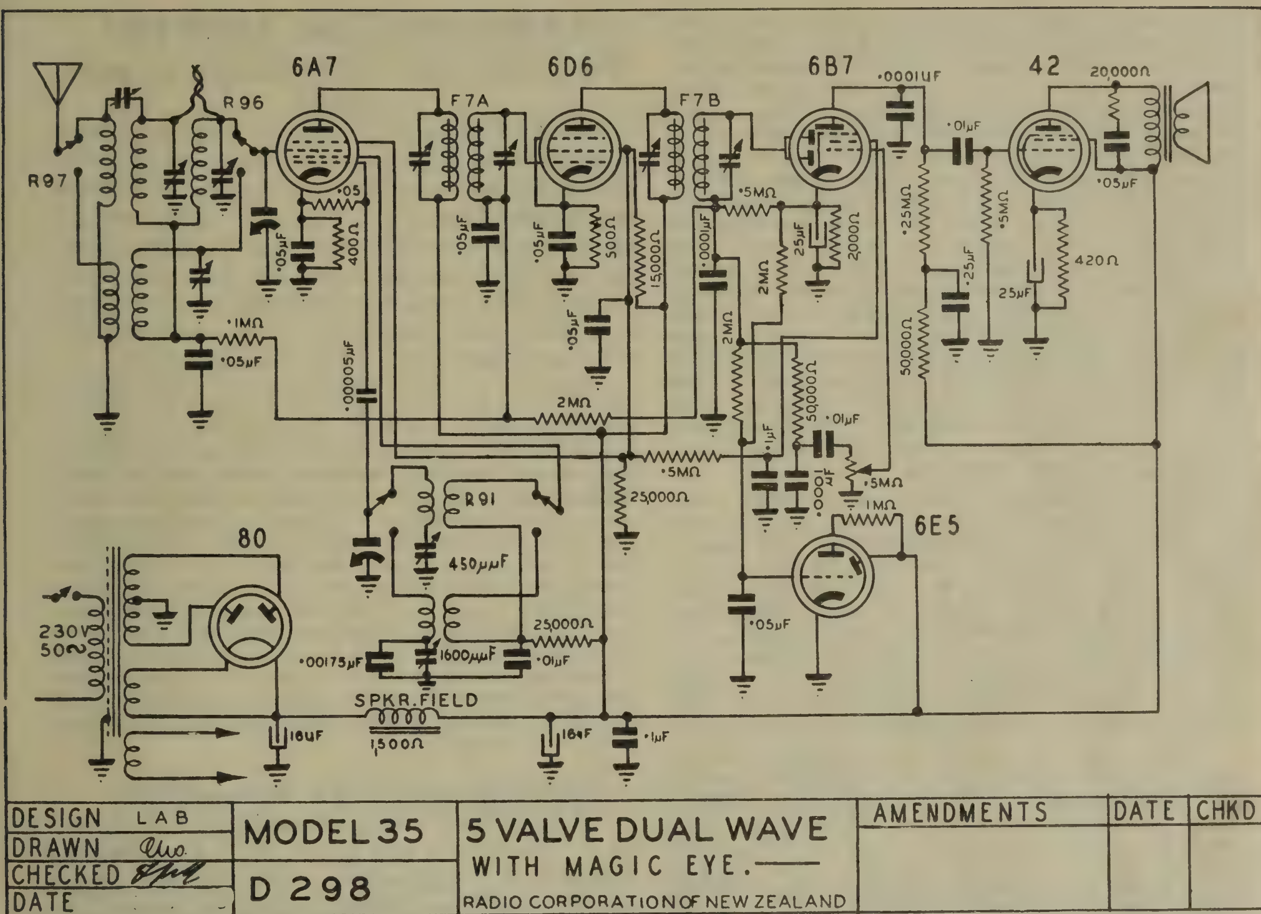
The **FIRST** thing to do is to remove the chassis from the cabinet and give it a good clean up—preferably with a forced-air jet, or otherwise carefully with a SOFT bristle brush, and clear out the cobwebs, dead beetles and moths, and other accumulated dust and fluff until we can see the original intrinsic beauty of the layout. While doing this, we keep a critical eye open for "burnt" marks on the mains transformer, the output transformer and field winding, for "fried" resistors, melted or "bloated" condensers, for loose or detached connections, and for "white paste" extrusion from the main smoothing electrolytics. If the electrolytics show this paste, we must replace them with new components before doing anything else, as they may be passing excessive current; that is, they virtually form low resistances across the supply rails. "Fried" resistors or "bloated" condensers can also be replaced, as they, too, have obviously "had it." In case of later mental aberration, it is advisable to make a note of what possible defects have been spotted and what remedies have been applied.

The **NEXT** thing is to take resistance readings of the mains transformer windings to ensure that these are apparently in order and that no open circuits exist. While on the job, we might just as well check the D.C. resistances of the output transformer and the speaker field coil, which in this instance should register 2000 ohms, while the output transformer primary should show some 500-600 ohms. Now we can check the mains supply cord for continuity if we we wish, or plug into the mains point and see if the valves light up, or, if we want to play very safe, we can unsolder the lead from the rectifier at the point A and insert the test meter (amp. range) in the circuit, with the positive terminal towards the rectifier and the negative terminal towards the supply to the set (see Fig. 1, which is a reproduction of the circuit given in the July, 1946, issue). Switch the meter to a high D.C. range (say 5 amps.), and then switch on and allow the set to warm up. If the needle hardly moves, we can change down to

> ***For the Serviceman:***
> **COLUMBUS MODEL 35**
> **On the opposite page is the next circuit in our series of New Zealand manufactured receivers. No special alignment instructions are required, except to note that the I.F. is 456 kc/sec.**

the 1-amp. range and then to the 100-milliamp. range, when, if all is well as far as current consumption is concerned, we may get a reading of some 60-80 ma. When taking this reading, the main tuning condenser should be turned fully open to minimum capacity, and with no signal applied the volume control should be full on. This state of affairs is also maintained when taking point-to-point voltage-current readings, as it places the receiver in its most sensitive condition.

While we have the milliameter in circuit, we may as well carry out a rough check on the current consumption of each stage, commencing with the output bottle, the 6V6GT. Take this out as smoothly as possible by holding it by the base (never remove valves by pulling on the glass envelope, as this may unseal it from the base and break the pin wires). As the valve breaks connection with the circuit, a click should be heard in the speaker, indicating that that unit is functioning. Of course, if the smoothing electrolytics were leaky, the smoothing would be inefficient and mains hum would be heard in the speaker, also indicating its functioning. Read the current drop on the meter, and this will represent roughly the combined screen-grid and anode currents of the 6V6. Replace the valve (when another click should be heard) and remove the 6Q7GT. The drop in current here should be practically unnoticeable on the 100-ma. range, as the anode current will be of the order of a fraction of a ma. on account of the 250,000-ohm anode load. Follow this by separately removing the 6K7 and the 6A8 valves respectively and noting the corresponding drops in current readings. The whole operation should be very quickly done, and immediately gives one a fair idea of the general operating conditions throughout the set. On adding up all the individual current drops, we should closely approximate to the total consumption. Allowance has



to be made for the normal leaks of the electrolytic condensers and for any steady currents through any bleeder resistance chains across the supply rails, such as screen-grid potentiometers, though in this particular case the reader will see that there are no such chains. The leakage of electrolytics varies somewhat with the make, but an average rate for a good high-voltage electrolytic will be 0.2 to 0.3 ma. per mf. at full working voltage. Thus a good 8 mf. condenser at 350 volts may be expected to pass 1.6 to 2.4 ma. of current. Bias electrolytics, owing to the low working voltage, pass less current, and a good 25 mf. 25v. D.C. unit may be expected to pass about 0.15 ma. Therefore, if we find that the total consumption is 80 ma. and the valves account for 60 of them, there is a 20-ma. leak somewhere to hunt up and account for. Naturally, our first suspicion would fall on the smoothing electrolytics, especially the first or reservoir one, which can be checked by joining the unsoldered rectifier lead to the field choke and inserting the milliameter between the condenser positive terminal and the wire junction, with the positive meter lead to the wire junction and the negative lead to the positive terminal of the condenser. The meter should be kept at a high ma. range for the switching-on operation, as there will be a high initial surge current; when the set has fully warmed up, the range can be gradually lowered till a fair deflection of the needle is obtained. Similarly, the output smoothing condenser can be checked by isolating it and inserting the meter here in the usual way.

By this time we have checked the general current consumption of the set and of the various stages, as well as the goodness of the electrolytics, and we have absolved the speaker from blame. We can now resolder and take point-to-point voltage tests, or we can use the signal substitution method. Let us consider the second method first, as it is quicker to describe. After switching on the set and signal generator and allowing them to warm up thoroughly, we pick off the audio frequency output only and connect it across the slider of the volume control and earth, as this is the input to the whole audio section. If no signal is heard from the speaker, we can either work towards or away from the speaker. We rather favour the latter, as it corresponds to the direction of the test in the other method. Suppose, therefore, we work back from the speaker. We connect the signal generator across the grid and earth of the 6V6, with the earth or negative clip to the chassis and the positive lead to the grid pin. If no 400 c/sec. note is heard from speaker, we must examine the 6V6 stage in detail, taking voltage readings at the anode, screen-grid, and cathode, by connecting the "D.C. volts" section of our test meter

across these points and chassis. This is quickly done, because the negative meter lead is clamped to the chassis and the positive lead just touched to the points in turn while switching the meter to the appropriate ranges. If the anode and screen-grid potentials are the same, the indication is that no current is being passed by the valve, since the screen is connected directly to the H.T. supply and the anode to the output transformer primary, which has a D.C. resistance of some 500 ohms, across which there should be an appreciable voltage drop. Also, if no current is being passed, the cathode voltage will be zero. If the anode shows zero volts, then there must be an open circuit in the output transformer primary circuit somewhere. It cannot be in the primary winding, as we have already checked that, so it must be at the anode connection. But this fault will have been suspected when the valve was removed, as the current drop would only have been that of the screen circuit, i.e., some 2 ma. instead of the normal 30-36 ma.

Current and voltage readings having been found O.K., we must look elsewhere, and in this circuit it can only be in the tone control system. Try turning the control to full on, i.e., the slider at the grid end (the tone control "pot" is the grid leak here), when a faint signal may be heard even if the .00025 condenser is shorted, but if no signal is heard we can prove this point by disconnecting the condenser at one end and soldering another in its place. Failing this, we must see whether the tone control "pot" is really earthed or open circuited.

Keeping the earth lead of the signal generator attached to the chassis, we next touch the positive lead to the grid of the 6Q7 (top cap), and if still no signal is obtained here it must be due to a faulty coupling condenser, the 0.05 mf. unit. If a signal is heard at the anode contact but not at the grid of the 6Q7, we must take voltage readings for the stage, as the fault may be an open circuit in the anode load circuit (250,000-ohm resistor), the 0.5 meg. grid leak circuit, or in the cathode circuit, which latter would be shown up by a zero voltage reading. After remedying any faults found here, we can make a final check by injecting the audio signal at the slider of the volume control again, when the signal should be heard very distinctly.

(To be continued.)

QUESTIONS and ANSWERS

THE INFINITE IMPEDANCE MIXER AGAIN

Mr. C. D. Johnson, Te Aroha, writes: "I have a set of commercial shortwave coils, and am wondering if they could be used with an infinite impedance mixer. The one point which troubles me is that, in your May and August, 1946, issues, the oscillator circuits given are both Hartleys, whereas these coils were designed for shunt feed to a 6K8. Also, would a 6F8 do instead of the 6SL7 mentioned by ZL2ML in his article?"

Although, as Mr. Johnson observes, the oscillator circuits shown in our pages for use with the infinite impedance mixer are both of the Hartley type, this is not essential to the success of the circuit. Any of the ordinary feedback oscillator circuits may be used, with the mixer cathode coupled to the oscillator plate via a small condenser. In our original circuit, a 0.01 mfd. condenser was shown coupling the oscillator to the mixer cathode, but this value was not intended to be rigidly specified, as almost any value from 0.0001 mfd. to 0.01 mfd. may be used, the smaller values being preferable, especially for shortwave work. A 6F8-G will be quite suitable for use as a combined oscillator and infinite impedance mixer. Since this tube has a higher mutual conductance than the 6SL7, a smaller grid-leak may be necessary to prevent "squegging."

* * *

SINGLE OR DUAL SPEAKERS?

Mr. F. M. Taylor, Auckland, writes as follows: "Some time ago I built the 6A3 Amplifier described in your magazine, using the later information kindly supplied by you to enable the Amplifier to be used with a P/M Speaker.

"The Amplifier is performing so well, even with the makeshift speaker, that I would like to get the best possible speaker or speakers to use with it. I should therefore esteem it a favour if you would advise me on the following points:—

(1) Since high-note speakers are not obtain-

able, would there be any gain by using a 6in. or 8in. speaker in conjunction with a 12in.? The 12in. speaker would be mounted in a vented loudspeaker enclosure, and the smaller speaker in the cabinet with the amplifier, or any other baffling to bring out the high notes.

(2) If you consider the above worth while, do you think a sufficient number of readers would be interested to warrant publishing a circuit giving details of the necessary filter network for the two speakers?

(3) What size speaker do you recommend to use with the 12in.?

Mr. Taylor's letter brings up several points of considerable interest to audio enthusiasts. In the first place, if high-fidelity single speakers, or properly-designed "tweeters" are not available, it is not generally realised that there is considerable advantage to be gained by using two "ordinary" speakers, together with a suitable dividing network, which allows each speaker to handle a portion of the audio range.

There is a tendency to regard this purely as a scheme for extending the overall frequency response of the system, but such is by no means the case. Even if two identical speakers of comparatively restricted frequency response are used, much better performance will result. The main reason for this is the elimination of much of the distortion that occurs **in the loudspeaker itself.**

In many cases the latter is by far the weakest link in the reproducing chain, and produces a great deal of cross modulation distortion. Tests undertaken of recent years show that this type of distortion does occur to a large extent in speakers, and, further, that it is by far the most annoying type of distortion to the ear. This is one reason why so many reproducing systems which show up so well on ordinary frequency response tests and on single frequency distortion tests can sound so poor when reproducing music. Although cross-modulation distortion can and does arise in amplifiers themselves, there should be very little of it in the "Quality 6A3 Amplifier" referred to by Mr. Taylor. Thus, the answers to his questions are as follows:—

(1) A 12in. bass speaker, in a vented enclosure, assisted by a 6in. or 8in. treble speaker, together with the appropriate dividing network, would certainly give better results than any single speaker, except perhaps one of the "high-fidelity" type.

(2) Although the subject is one which is likely to interest a number of readers, it is not possible for us to publish such an article immediately, in view of the large amount of laboratory work involved in thoroughly test-

(continued on page 48)

OUR GOSSIP COLUMN

Charles Forrest, Manager and Chairman of Directors of International Radio Co., Ltd., New Zealand Industries Ltd., New Zealand Wires and Cables Ltd., and Bobbie Pins Ltd., has recently returned by Pan-American Airways from an extended visit overseas.

Mr. Charles Forrest.

Whilst in U.S.A. he contacted his many friends in the radio, electrical and associated industries. He spent some considerable time making a complete survey of the industries in which his various companies are interested, and was able to make very satisfactory arrangements regarding the supplies of essential raw materials and machinery.

Mr. Forrest was given a very warm welcome on arrival by his many associates in Auckland.

* * *

A new name becoming familiar to the radio industry is that of the Russell Import Company which has been formed to distribute Philco and many other subsidiary lines. Russell Import commenced business in October, 1946, occupying premises at 100 Dixon Street, Wellington. The executive is headed by William Young, Manager, who prior to overseas service with the R.N.Z.A.F., was with a prominent Sales Organisation.

Sales Manager is Jack Speers who, although a New Zealander by birth, lived in America for many years, and just prior to the war was Philco Sales Representative for the Philippines area.

In 1942, at the outbreak of war, he was captured by the Japanese by whom he was held prisoner in the infamous University of Santo Tomas. After escaping, he went into the hills where he assisted the guerillas to operate a secret radio station known as the "Voice of Freedom." Six months later he was recaptured, and, as a result of his activities whilst at large, received extremely brutal treatment. In fact, he was on the point of starvation when he was released by the American Forces.

After four months in a hospital in California and a major eye operation necessitated by ill-treatment whilst in Jap. hands, he returned to New Zealand. During his imprisonment his weight dropped from 14 st. 4 lb. to 8 st. 8 lb. However, when seen in his office last week, it was apparent that Jack is back to his normal weight once more, and is indeed looking very fit.

* * *

Ted Palmer, of Inductance Specialists, and his wife, have been spending their vacation at Taupo. Most of the time was taken up in chasing the elusive trout—apparently without much success.

* * *

On entering National Carbon's office the other day, we were greeted with "Did you hear about Ron Greenwood's eight and a half pounder?" This statement did not fail to grip, so we probed the question a little further, and discovered the fact that Ron and George Ferris—Christchurch Representative of Radio (1936) Ltd.—had also been to Taupo. The object was "general reconnaissance" of the pools and streams, in which, rumour hath it, many trout reside. Great were the results of this expedition, for, during this trip, Ron caught his 8½ pounder, as well as a number of smaller fish. Charles Hart confirms the "kill" as he says he tasted same.

George Ferris, by the way, is recognised as one of New Zealand's finest trout fishermen, his book "Trout Fishing in N.Z." being in the hands of the publishers.

Speaking of National Carbon, we are pleased to report that Rex Lulham has recovered and is back at the office once more.

* * *

Messrs. E. Bowen, of Isaac Brown's, Paeroa, and Fairclough, of Fairclough Radio Ltd., Napier, have been recent visitors to Wellington.

* * *

Bert Peoples, S.T.C. Auckland Representative, has been attending a conference at Head Office, Wellington.

* * *

Bill Field, of Wilkins and Field, Nelson, is sporting a new Plymouth car—nice work, Bill!

* * *

Bernie Judd, of Radio Specialties, Tauranga, has been in these parts. Bernie is one of Tauranga's oldest and most progressive radio and electrical dealers. His business activities and cabins at the "Mount" keep him well occupied at present.

* * *

To those who noticed our misprint in this column last month and wondered: Rev Grover, chief of Hohner Electrical Co., spent Christmas holidays at Mercury Bay with his wife, Isobel Grover.

* * *

Reg Boreham, who for some years has been with S.O.S. Radio Service, Auckland, and who during the war years managed the business whilst Jim Eckford served with the Army, has now joined the staff of Arnold and Wright, and Reg will look after their interests in Auckland. We extend our best wishes to Reg in his new appointment.

SERVICE TUBE TESTS

By the Engineering Department, Aerovox Corporation

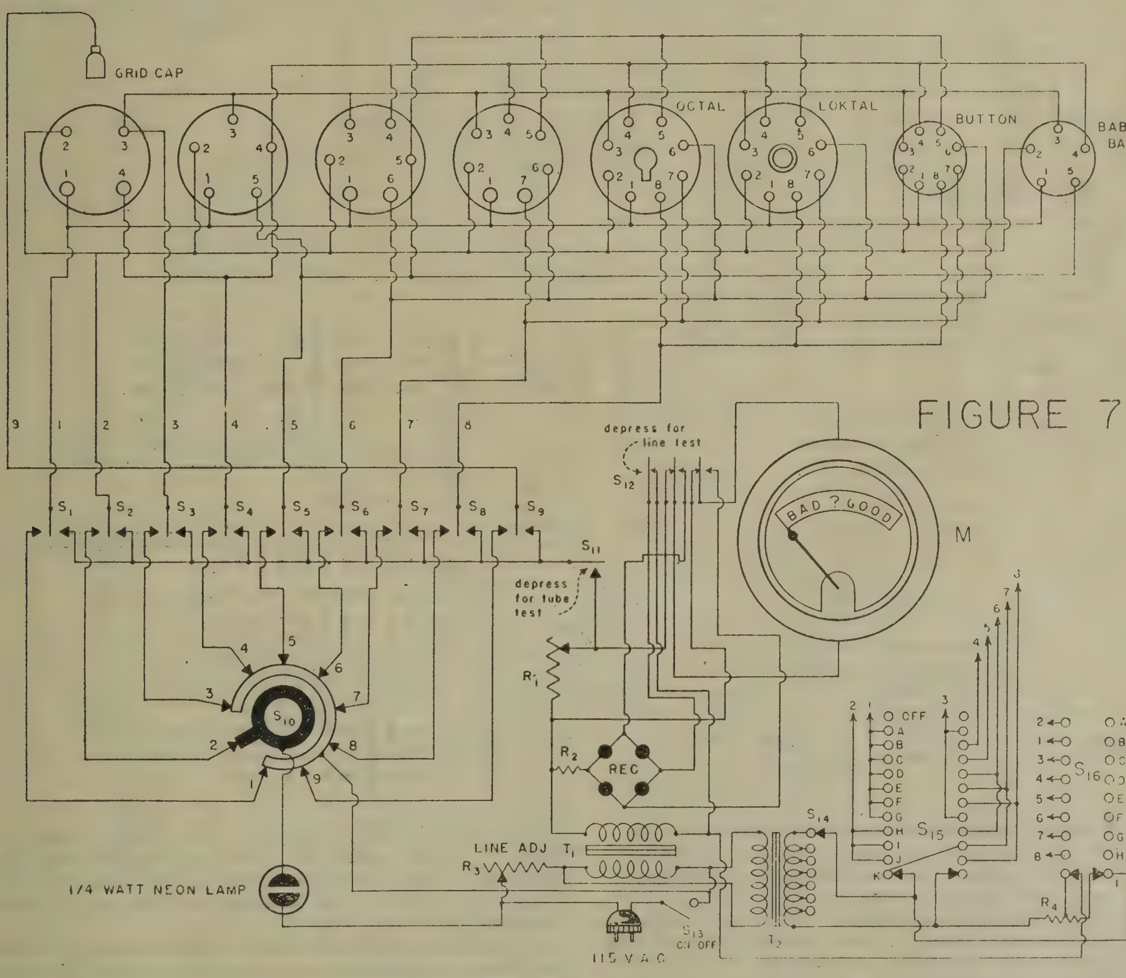
PART 3. COMPLETE TEST SETS

In Parts 1 and 2 of this series, we described the simple circuits used for rapid checking of emission, transconductance, and power output of vacuum tubes. Any one of these circuits might be set up, with no alterations, for testing one particular type of tube. But because many different bases and base-pin arrangements are employed in the large number of tubes presently available, rewiring of the simple test circuit would become necessary in order to check other types of tubes.

In professional service tube testers, a socket is provided for each type of tube base, and a circuit switching arrangement permits test connections to be made quickly to proper socket terminals. This flexible feature in effect re-wires the test circuit for each type of tube to be tested.

It is customary for the scale of the indicating meter in these test sets to be graduated in English units—that is, to read BAD—?—GOOD or REPLACE—?—GOOD, with the question mark at or near centre-scale.

Complete service tube testers of recent manufacture fall into two categories—emission testers and dynamic transconductance testers. The schematics of these instruments, in the order just named, are shown in Figs. 7 and 8. These drawings reproduced here are not the exact schematics employed by particular manufacturers of tube testers, but are functionally correct and indicative of those arrangements in actual commercial instruments.



The first type, shown in Fig. 7, checks emission of all tubes and has a separate short-circuit test. The emission test portion of the circuit is an elaboration of the arrangement shown in Fig. 1 (Part 1). The short-circuit test portion is identical with the circuit

in Fig. 6. The second type of tester checks dynamic transconductance of all grid-type tubes except class-B amplifiers; power output of class-B tubes; plate current of rectifiers, diodes, and the diode sections of multipurpose tubes; and short circuits in all types. The transconductance portion of the circuit is an adaptation of the circuit in Fig. 3-B (Part 1), the these switches are thrown to the left, all tube electrodes are connected to the short circuit tester, which has the same arrangement as that shown in Fig. 6, Part 1. When these switches are thrown to the right, they connect the various tube electrodes (except cathode) together and to the milliammeter, M, and the A.C. test voltage. The set-up then is

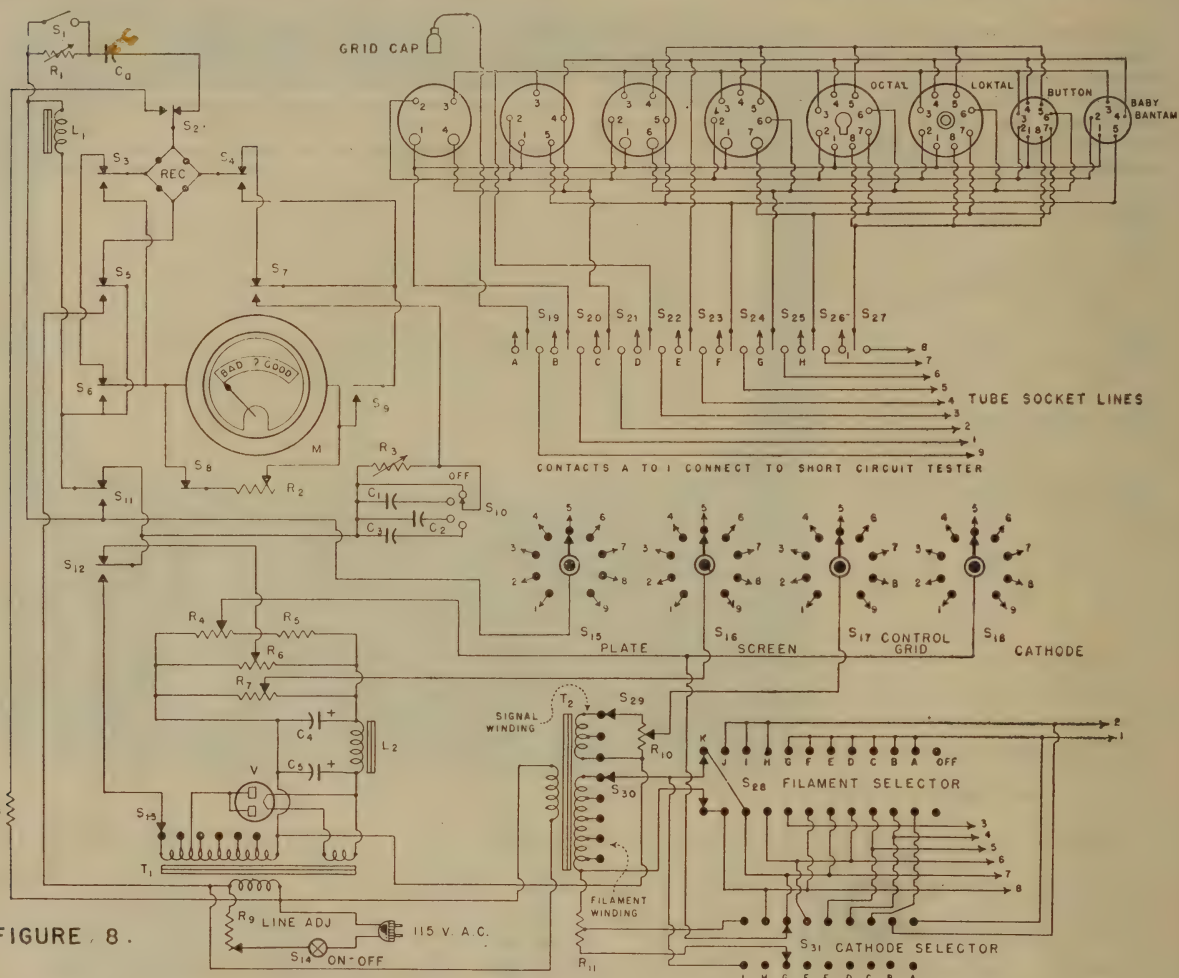


FIGURE 8.

class-B power output portion an adaptation of Fig. 4, the diode and rectifier portion is identical with Fig. 5, and the short-circuit portion identical with Fig. 6.

It will be noted that in each of these circuits, Figs. 7 and 8, the various tube socket terminals are connected to corresponding lines numbered according to standard tube base-pin numbering. These lines, labelled 1 to 8 in the drawings, correspond to socket terminals having the same numbers. Line 9 is connected to a grid cap connector for use with tubes having the top-cap terminal. Switches connect each of these lines to appropriate points of the test circuit.

EMISSION TESTER

In Fig. 7 ,the circuit schematic of a type complete emission tester, the tube socket lines terminate in 2-position single-pole toggle switches, S_1 to S_9. When identical with the emission test circuit shown in Fig. 1. Since most tubes do not employ all nine connections, only those switches which actually communicate with base connections are thrown to either position.

R_1 is the adjustable shunt resistor which enables the meter range to be set so that the end-of-life point for each type of tube is coincident with centre-scale deflection. No meter reading is obtained until push-button switch S_{11} is depressed. This prevents damage to the meter when initial instrument settings are being made.

In order that tests may be made at all times at the same line voltage level, a line-voltage adjustment rheostat, R_3, is included in the circuit. When push-button switch S_{12} is depressed, the milliammeter is

connected to the output of the oxide rectifier, REC; and the rectifier is connected, in turn, across the 50-volt secondary of transformer T_1 through a multiplier resistor, R_2, of such size that centre-scale deflection of the meter is obtained when R_3 is at a designated setting.

The single pole rotary switch, S_{14}, selects the proper filament voltage for the tube under test from the secondary taps of transformer T_2, and this voltage is applied to the proper socket terminals by the 2-pole filament terminal selector switch, S_{15}. This filament selector arrangement has been described previously in some detail in connection with the short circuit tester shown in Fig. 6, Part 1.

A second two-pole selector switch, S_{16}, selects the proper cathode terminal. In position 1, this switch selects as the effective cathode the filament of directly-heated tube types. R_4 is a 100-ohm centre-tapped resistor which is shunted across the filament. The centre tap becomes the test-circuit return.

The following example is offered to illustrate how settings are made with the emission tester. Assume the tube under test to be a type 75. The tube is placed in the six-pin socket and the grid cap clipped to the tube's top-cap connector. S_{14} then is set for 6.3 volts, and S_{15} to position D (socket terminals 1 and 6). S_{12} then is depressed, and R_3 set for centre-scale deflection of the meter. For the emission test, R_1 is set to the scheduled value which will permit centre-scale meter deflection for a type 75 tube at its end-of-life point; cathode selector S_{16} is set to position E (socket terminal 5); S_2, S_3, S_4, and S_9 are thrown to the right, and pushbutton S_{11} is depressed for a tube-quality reading on the meter.

For the short-circuit test, all settings remain the same, except that S_2, S_3, S_4, and S_9 are thrown to the left, and S_{10} is rotated while the neon lamp is watched for the continuous glow that indicates a short circuit.

TRANSCONDUCTANCE TESTER

The second type of tester (see Fig. 8) has many circuit features which are identical with those in the emission tester (Fig. 7). For example, the sockets are connected to lines numbered in the same way; and the filament voltage selector (S_{30}), filament terminal selector (S_{28}), and cathode selector (S_{31}) are the same as those shown in Fig. 7.

Important circuit differences are: (1) The internal power supply comprised by transformer T_1, A.C. voltage selector S_{13}, rectifier tube V, filter choke L_2, filter capacitors C_4 and C_5, and D.C. voltage selectors R_4, R_6, and R_7; (2) a ganged nine-pole two-position switch S_{19} to S_{27}, rather than the separate toggle switches shown in the emission tester, which shifts the circuit from tube-test to short-test; and (3) the selector switches S_{15}, S_{16}, S_{17}, and S_{18}, which apply D.C. operating voltages to the tube electrodes.

The short-circuit tester is the same as that shown in Fig. 7 and explained in detail in Part I. It is connected to the open lines (labelled in the diagram "to short-circuit tester") from switch S_{19} to $_{27}$, and has been omitted from the drawing in order to reduce the complication.

Line Voltage Test

S_2, S_5, and S_8 are sections of a triple-pole, two-position pushbutton switch which when depressed connects the oxide rectifier, REC, through the multiplier resistor, R_8, across the primary of transformer T_1, and removes the shunt rheostat, R_2, from across the meter terminals. The seven-pole, two-position switch ($S_{3, 4, 5, 6, 7, 11, 12}$) is a changeover component and is in the "up" position for this test, as shown in Fig. 8. Pushbutton switch S_9 must be depressed. The resistance of R_8 is so chosen that centre-scale deflection of the meter will be obtained when R_9 is set for correct primary voltage. This point is generally marked by a single line on the meter scale, and designated LINE OK.

Transconductance Test.

After all switching operations are completed, the final circuit set-up for the transconductance test is identical with Fig. 3-B in Part 1. The tube to be tested is inserted into the proper socket. Toggle switch S_{19} to $_{27}$ then is thrown to the right, proper filament voltage is selected by S_{30} and applied to the proper filament terminals by S_{28}, switch S_{31} is set to select the proper cathode terminal of the socket, changeover switch $S_{3, 4, 5, 6, 7, 11, 12}$ is in the up position, potentiometers R_4, R_6, and R_7 are set respectively for correct values of tube cathode, plate, and screen D.C. voltages, selector switches S_{15}, S_{16}, and S_{17} are set to distribute these voltages to the proper socket terminals, switch S_1 is closed, R_2 is adjusted for a setting permitting centre-scale deflection of the meter for borderline transconductance of the tube type under test, switch S_1 is closed and S_{29} set for a 1-volt R.M.S. grid signal, and pushbutton S_9 is depressed for a tube-quality reading on the meter scale.

Class B Test

All settings are made exactly as described for the transconductance test, except that switch S_1 is opened, a higher value of signal voltage must be selected by S_{29} and R_{10}, and shunt rheostat R_2 must be set to its OFF position (open circuit). The final circuit arrangement is similar to that shown in Fig. 4 (Part 1), except that choke L_1 is used in lieu of a plate load resistor. Resistor R_1, which must be set to a different value for each tube type, corresponds to Rm in Fig. 4. This resistor makes centre-scale deflection of the meter, M, correspond to the critical power output value for the class-B tube under test. S_9 is depressed for a tube-quality deflection of the meter.

Rectifier and Diode Test

For this test, changeover switch $S_{3, 4, 5, 6, 7, 11, 12}$ is thrown to the down position. R_3 is set to the proper rectifier load resistance value for the tube under test. S_{10} is set for recommended value of load capacitance for the tube. Filament voltage and cathode are selected in the same manner as described in earlier portions of this article, by means of S_{28} and S_{30}, and by S_{31}. A.C. plate voltage to be applied to the rectifier or diode plate is selected by switch S_{13} and is applied to the proper socket terminal by S_{15}. Shunt rheostat R_2 is set to a resistance value

which will permit full-scale deflection of the meter to correspond to end-of-life plate current for rectifier tubes. Pushbutton switch S_9 is depressed for a tube-quality deflection of the meter. After checking one rectifier or diode section of a dual tube, S_{15} is set to connect the second plate, and the remaining section tested. The final rectifier test circuit is identical with the one shown in Fig. 5, Part 1.

Short-circuit Test

After the tube to be tested has been inserted into the proper socket of the tube-tester and has reached normal filament temperature (filament voltage being selected by S_{28} and S_{30}), changeover switch S_{19} to $_{27}$ is thrown to the left and the short-circuit test made in the same manner already explained in the description of the emission tester, Fig. 7.

GAS TEST

Since gassy vacuum tubes occasionally cause radio receiver trouble, it is desirable to check for the presence of gas. Not all service tube testers make provision for this test. A simple method consists of observing the plate current of the tube under test while a one-megohm resistor connected between control grid and cathode is successively short-circuited. If the tube is gassy, a grid current will flow through the resistor, changing the grid bias and causing a change in the plate current reading. Normal D.C. operating voltages must be applied to each tube electrode during the gas test.

NOISE TEST

Noises other than microphonics develop in tubes from a number of causes. Damaged electrodes, leads, or supports, and similar causes give rise to hissing, cracking, frying, or buzzing noises in high-vacuum tubes. Noise is checked best by placing a pair of headphones in some appropriate leg of the tube circuit. Generally this will be the plate lead. However, tubes drawing large values of plate current which might damage the headphones, may be tested by connecting the headphones across a plate-load resistor in series with a 0.1 or 0.25 mfd. capacitor. While listening for noise, it is advisable to strike the outside of the tube sharply with the finger-tip or with a rubber mallet. Some commercial service tube-testers provide a headphone jack for this test.

HUM TEST

The hum test is made in the same manner as the noise test, except that the operator listens for hum only. Hum, such as the type produced by defective cathodes and some forms of interelectrode short circuit, generally is of 60 cycles frequency. In commercial service tube-testers, the headphone jack serves for noise, hum, and microphonic tests.

TEST FOR MICROPHONICS

With headphones inserted in the test circuit, as explained under NOISE TEST and HUM TEST, the outside of the tube is struck sharply with the finger-tip or with a small rubber mallet while the operator listens for the bell-like sounds that typify microphonics. This test will locate a microphonic tube unfailingly. However, the operator must keep in mind that certain tubes, particularly some of the older style battery types, are normally microphonic and should not be rejected for showing this characteristic.

TRADE WINDS

Eric Undrill, Factory Manager of Philips Electrical Industries, has returned to New Zealand after an extensive tour of the Philips organisations in Holland, England and America.

Travelling by B.O.A.C. aircraft, he arrived in England within six days after an uneventful trip.

After spending a month at the English factory at Mitcham, he attended a conference of Factory Managers held at Eindhoven. Managers from Europe, South Africa and America had gathered here to discuss the present-day situation, with particular reference to a study of war-time developments in as much as they applied to domestic set manufacture. A comprehensive investigation found no new major development in domestic broadcast receivers and, as many other authorities in the electronic field have stated, the war-time research in electronics will undoubtedly have a great influence only on tele-communications, television, navigational aids and all high frequency radio equipment.

In Holland many production problems have to be faced, mainly due to the import of raw materials and the substitution of many components. These difficulties, however, are not insurmountable, and production of all types of electronic equipment is well under way. In no small measure can the success of this be attributed to the excellent industrial understanding between employer and employee—their common struggle is one for production and export, backed by the knowledge that upon their efforts depends the economic future of the country.

As in many other countries, so in Holland manpower problems are difficult—so much so that many thousands of factory workers are transported daily from Belgium, the trip itself occupying three hours.

Bad transport conditions brought about by the war have done nothing to improve matters. Most road and rail bridges were destroyed during the war, and continuity of transport was accomplished by means of Bailley and pontoon bridges, etc.—but by a great effort all bridges have been restored.

The Philips factory itself was severely damaged by the R.A.F.—such action being necessitated by the fact that the Nazis were using these vast facilities for their own war production. However, throughout the occupation years, the Philips staff conducted an immense amount of research, a great part of which was pure physical research. This fact is all the more astounding when it is realised that such work was carried on right under the eagle eye of the Germans.

The Dutch suffered greatly and are still hard hit, but their spirit of co-operation for the common good of their country cannot but help give them their rightful place among the nations—a place which they richly deserve.

BRITISH INSULATED CALLENDER'S CABLES LTD.

As from 1st January, 1947, the interests of "British Insulated" cables and manufactures, previously handled by Messrs. P. R. Baillie and Co. for the Wellington Provincial District, has been transferred to the National Electrical and Engineering Co., Ltd. Mr. Frank Davidson, who has been associated with Messrs. P. R. Baillie and Co. for many years, has joined the staff of the National Electrical and Engineering Co., Ltd. These new arrangements will enable the National Electrical and Engineering Co., Ltd., to ensure continued uninterrupted service with "British Insulated" cables and manufactures.

Mr. P. R. Baillie wishes to thank all clientele for the goodwill mutually enjoyed over a considerable number of years, and trusts that such cordial business relations so long existing will also be enjoyed through the agency of the National Electrical and Engineering Co., Ltd.

THE FOUR-BAND AMATEUR'S TRANSMITTER

Since our February issue went to press, we have discovered that two errors crept into the circuit given on page 9. First, the .25 meg. grid-leak of the right-hand half of the 6SN7 Franklin Oscillator should be returned to earth, not as shown, to cathode. Second, the 6AC7 buffer, when switched to the V.F.O., has no grid-leak. A .25 meg. resistor should be inserted, therefore, between the 6AC7 side of the V.F.O. coupling condenser and earth.

The 6AC7 buffer has been shown with 250v. on plate and screen. The transmitter, as now in use, has had a dropping resistor of 50k. inserted between the 250v. H.T. point and the 8 mfd. screen bypass condenser of the 6AC7. This does not impair the operation, but results in longer life for the tube.

A Practical Beginners' Course

PART 8

Having now built and experimented with several types of crystal set, the time has come when we can turn our attention to the use of valves, and to the building of our first valve set; but before we can undertake this, we must learn something, if only a very little, about electricity and electric currents. Although the crystal sets we have made handle radio frequency currents, these are so small that it is impossible for us to harm any of the equipment (crystal detector or headphones, for instance) by making wrong connections or by not understanding very much about what electric currents do. However, when we come to buy our first valve, we need to know a little more than we do now. If not, we will be in danger of burning out our brand new valve, or of ruining the batteries before we have had any use from them. So now, although this is a practical course, we must say a little about what electricity is and how it is controlled.

ELECTRONS AND WHAT THEY ARE

The first point to be understood about electricity is the nature and behaviour of a minute particle called the **electron,** of which most of you have no doubt heard.

Electrons form a very important part of everything in the world about us, although they are so minute as to be invisible through even the most powerful microscope. All **matter** (which is simply another name for material) is made up of very minute particles known as **atoms** and **molecules.** Some substances, known as **elements,** contain atoms which cannot be broken down by chemical means into any simpler substances. Many of the things and substances we know quite well are elements. For instance, most metals such as iron, copper, zinc, and aluminium; many gases such as hydrogen, oxygen and neon; and other solids such as sulphur, carbon and silicon, are all elements.

There are only 92 elements, and we know that it is not possible for there to be more than this. But there are a great many more than 92 substances in the world. All the others are what are called **compounds,** and the smallest piece of these that can exist is called a **molecule.** For instance, ordinary salt is a compound. We know this because it is possible by chemical means to break up salt into **sodium,** a soft metal, and **chlorine**, a greenish gas. However, all attempts to break up sodium or chlorine into simpler substances have failed. In fact, a molecule of salt is made up of one atom of sodium combined with one atom of chlorine.

Now, until the late years of last century, it was thought that atoms were completely indivisible, but about that time it was found out that they are not solid masses of material, but are made up in a way that is very reminiscent of the sun and its planets.

Atoms, it was discovered, consist of a more solid central nucleus or core, where practically all the weight of the atom resides, surrounded at some little distance by one or more much smaller particles, almost without weight, which are called electrons. We now know that the nucleus is made up of a number of different kinds of smaller particles, but the part of the atom that is of most interest here is the **electron.** The reason for this, is that what we know as an electric current is simply a movement of electrons.

CONDUCTORS AND INSULATORS

All atoms, as we have already seen, consist of a central nucleus, round which are rotating a certain number of electrons, much as the planets revolve round the sun. These external electrons are perhaps the most important thing about an atom, because their number and arrangement determine just how the atom will behave chemically and physically. Since we are more interested in their electrical behaviour, we will use this to illustrate the point. Some elements are good conductors of heat and electricity, while others are not. This is because some elements have only a loose grip on the outermost electrons in their atoms, and these electrons are able to move about comparatively freely. These are the **conductors,** as would be expected from the fact that an electric current is a movement of electrons. Other elements, known as **insulators,** do not readily conduct heat or electricity because the outer electrons in their atoms are tightly held and cannot easily escape from their own atoms. In a conductor, the outer electrons are constantly being interchanged from one atom to the next, because these electrons are loosely held, so that if the right conditions exist, a general drift of these electrons can occur in some particular direction. If this occurs, there is said to be an electric current flowing in the material.

HOW IS A CURRENT CAUSED?

If, as has been stated, an electric current consists of a movement of electrons from one place to another, how can such a current be caused to take place? There are several methods, all of which have their own special application, but all of them work in the same fundamental way. That is, by causing a temporary removal of some of the "free" outer electrons of a conductor.

Now, in a piece of conducting material, such as a copper wire, each of the many millions of atoms making up the piece has just the right number of outer electrons. If, by some means or other, an electron is removed from one of these atoms, this atom develops a strong attraction for all the movable electrons in the vicinity. Now, when one of these, in the course of its normal movement round its nucleus, approaches closely enough to the atom which has lost its electron, it will be "grabbed" as it were, bringing our original atom back to its normal state, and leaving another atom one electron short. This process continues, the second atom catching an electron belonging to a third, and so on. The sum total of all this activity is a drift of electrons along the wire in which these atoms exist. This drift is very similar to the flow of water in a stream, and it is for this reason that it is called a **current** of electrons, or an electric current.

If the current consists of a large number of electrons passing a particular point each second, it is a large current, but if only a few electrons pass each second, the current is a small one. The two can be likened to two rivers, a large one and a small one. The large river has a bigger current, because in it, more water is passing a given spot on the bank than is the case with the small one.

The oldest, and still an important way of causing atoms to lose electrons and so bring about an electric current, is the chemical method, used in batteries of all kinds.

For example, if we have a bath of dilute sulphuric acid, and in it we dip part of two pieces of metal, one of zinc and one of copper, an electric current will flow through a wire that is connected between the copper and the zinc, outside the acid. This is because the chemical action of the acid on the zinc causes electrons to be drawn from the part of the copper that is immersed in the acid, and other electrons to be deposited on the zinc. Thus, when the two are connected by a wire of some conducting material, the electrons flow round the wire from the zinc to the copper, and inside the bath from the copper to the zinc. In the process, both the zinc and the acid become used up, forming a chemical compound called zinc sulphate, but at the same time the current which flows in the wire can be made to do useful work. For instance, if the "wire" is the filament of a torch globe, the current will have made it white hot, giving us a light.

Generators, dynamos, and all such machines which generate an electric current by being rotated mechanically, depend for their success on the fact that electrons are affected in their movements by the action of a magnet.

ELECTRICAL RESISTANCE

As mentioned above, some materials are known as conductors because electric currents can readily be made to flow through them, while others are called insulators, and in these it is very difficult to cause a current to flow. In fact, in an insulating material, so little current flows that for all practical purposes we can say that there is no current at all.

However, the position is not quite so simple as this really, because some materials are better conductors than others, while some are better insulators than others. Indeed, there are some materials known as semi-conductors because their electrical behaviour is not exactly that of a conductor or yet that of an insulator. These varying properties of different materials are very helpful to us when we are using electricity, because they enable us to control our currents in any manner we choose.

In our crystal sets, as in most other electrical things, there are parts of the circuit where we want currents to flow as easily as possible. This is the case with the coil. The radio currents in it are wanted to be as large as possible, so that we use copper wire, which is one of the best electrical conductors known. At the same time, we want the currents to flow only along the wire of the coil, and not across the coil from one turn to the next. Thus, we cover the copper wire with cotton thread, which is an insulator, and prevents currents from flowing between the turns of the coil when they have been wound touching each other. Similarly, we use a wooden insulating base-board on which to build the set, so that the aerial currents will not be able to flow through the material of the board to the earth terminal, but will have to pass through the aerial coil before flowing to earth through the earth wire of the set.

Probably, you will have noticed before this that most conductors are made of some kind of metal. Copper wire is used so much in electrical work because it is a plentiful and not too expensive material, and is one of the best conductors. In special cases, where absolutely the best conductivity is wanted, silver wire is used, because, although expensive, it is a better conductor even than copper.

Another and a better way of expressing this is to say that copper offers more **resistance** to the current than does silver. Again, iron has more resistance to the passage of a current than copper. Insulators, therefore, can be said to offer a great deal of resistance. So much, in fact, that hardly any current can pass through them at all. Thus, the property of materials which determines how well they conduct, or how good they are as insulators, is known as their **resistance,** and this is a very important electrical quantity. It can be likened to the resistance offered by various materials to the flow of water in a pipe. If the pipe contains only air, there is very little resistance to the flow of water. If the pipe is full of large irregular stones, water can still flow through the pipe, but not so quickly. If the pipe is full of sand, this shows even greater resistance to the flow of water, which can now seep through only slowly. Again, if there is a plug of clay somewhere in the pipe, the clay's resistance is so great that practically no current of water can flow at all.

ELECTRICAL PRESSURE

When an electric current flows, it does so not of its own accord, but because a battery or generator has made it do so. In the same way, water will not flow in a pipe unless some force makes it. This force or pressure can be produced by a pump, which may, therefore, be likened to the battery or generator in the electrical case. Thus, the purpose of the battery

(continued on page 48)

FREQUENCY MEASUREMENT

PART VII

USING THE STANDARD AS NOW CONSTRUCTED

Having described the construction, action, and adjustment of the 100 kc/sec. multivibrator, it remains to be seen what can be done with this extension of the original 1000 kc/sec. oscillator and harmonic amplifier.

It will be recalled that the circuit arrangement is as follows:—The 1000 kc/sec. oscillator feeds a buffer stage. This, in turn, feeds a 6AC7 harmonic amplifier, which provides harmonics of 1000 kc/sec. The 1000 kc/sec. buffer also has a variable output which provides the synchronising voltage for the 100 kc. multivibrator. The output of the latter is taken to a further 6AC7 harmonic amplifier whose plate is connected directly to the plate of the first 6AC7. Thus, the common output of the two 6AC7's consists of 1000 kc/sec. and its harmonics and 100 kc/sec. and its harmonics. In addition, due to the non-linear action of the 6AC7's, sum and difference frequencies are produced between the two series of harmonics, in such a way that all frequencies may be found in the output which conform to the formula:— $1000\ A \pm 100\ B = f$, where A and B are harmonic numbers of the two series, ranging from 1 (indicating the fundamental) to the highest harmonic which can be detected.

For example, the 2nd harmonic of the 1000 kc/sec. will beat with the 5th harmonic of the 100 kc/sec. to give 2000 ± 500, which are 2500 kc/sec. and 1500 kc/sec. respectively. In this way, it can be seen that the output contains a signal every 100 kc/sec. from 100 kc/sec. to as high as we please. Thus, the switch which enables the 100 kc/sec. multivibrator to be turned on or off allows us to select either a complete series of signals spaced 1 mc/sec. apart, or a complete series spaced 100 kc/sec. apart, just as we wish.

Obviously, this is a much more flexible arrangement than the 1000 kc/sec. series alone, as it enables calibration of receivers or oscillators to be carried out at every multiple of 100 kc/sec. up to several megacycles per second. Indeed, for many purposes, such a frequency standard might be considered adequate. In amateur transmitting circles, for example, it is not often necessary to know one's exact frequency, as long as it is known definitely to be within the prescribed band. For example, the equipment we have described will specify exactly the limits of any band whose ends are at frequencies that are multiples of 100 kc/sec.

RECEIVER CALIBRATION

As an initial example, let us take the case of a receiver which has been built, and whose dial requires calibration. We will assume that a nominal range of 2.5-7.5 mc./sec. is to be covered in the lowest frequency band, and that the coils have been wound so that the frequency coverage will be at least approximately correct.

The equipment required will be an auxiliary receiver with which to tune in WWV, and the home-built frequency standard.

The first step is to tune in WWV on the auxiliary receiver, and set the 1000 kc/sec. oscillator to exact frequency by the method described in Part II of this series. If the 100 kc/sec. multivibrator has been adjusted as described in Part VI, it will automatically lock in when fine adjustment of the 1000 kc/sec. oscillator is made, so that no further adjustment should be necessary.

Next, make sure that the 100 kc/sec. multivibrator is switched off, leaving only the 1000 kc/sec. series in the output of the standard. The latter is now coupled very loosely to the receiver to be calibrated. This is best done by wrapping the output lead once or twice round the aerial terminal of the set, making sure that metallic connection is **not** made, as this would give far too much coupling. It may be sufficient with a sensitive receiver simply to place the output lead of the standard somewhere near the aerial lead of the receiver.

When this is done, tuning the receiver should bring in as signals the harmonics of the 1000 kc/sec. oscillator. Each should be accurately tuned in, and a mark made on the dial at each pointer setting, or if a numbered dial scale is used, the dial reading for each signal should be noted. If the wave range of the receiver is approximately correct, there should appear on the dial five signals at 3, 4, 5, 6 and 7 mc/sec. respectively. The one remaining thing that the frequency standard will **not** indicate is whether

the five signals are the correct ones, or whether the coverage of the receiver is incorrect and the first signal is 4 mc/sec. or even 2 mc/sec. For this purpose, other means may be resorted to. Several expedients may be used here, and that which is most convenient will depend on what other equipment, if any, is available.

Should no extra equipment be handy, the point can be settled by listening for WWV on the receiver which is being calibrated. This may entail waiting, but once WWV is able to be received on 5 mc/sec., will take no time at all, since listening need be carried out only on one or two of the calibrated points, until it is discovered which of them is 5 mc/sec. When this has been identified, the remaining points may be labelled by counting on either side of the 5 mc/sec. mark.

If a signal generator or other calibrated oscillator is available, which of the points is 5 mc/sec. may be decided with its help. Note that for this purpose an accurately calibrated oscillator is not necessary, as all that is required of it is to distinguish between 4, 5 and 6 mc/sec.—not a very difficult job. This auxiliary oscillator is tuned to its nominal 5 mc/sec. mark, and the signal is tuned in on the receiver under calibration. Unless the auxiliary oscillator is a very long way out, it is now a simple matter to tell which of the calibrated points lies nearest the signal from the oscillator, and is therefore 5 mc/sec.

Yet a third method of identification is to listen on the receiver being calibrated, for signals of known frequency, other than WWV. In the present case, either the 3.5 or 7 mc/sec. amateur bands could be identified by listening tests, but for preference both should be logged, as a check. In using this method, the type of receiver being calibrated should be given consideration, as with some superheterodynes image responses might be mistaken for "real" responses, and lead to mistaken results. However, care and common sense, rather than elaborate equipment, will carry the day, especially if two methods are used as a cross-check.

Once the megacycle points have been calibrated, the 100 kc/sec. points may be inserted very easily. The multivibrator is switched on, providing the 100 kc/sec. series of signals. Each of these is tuned in, starting from one of the megacycle points. For example, the receiver is tuned to 3 mc/sec., which point has already been calibrated. The tuning is now moved towards the high frequency end of the scale. The first signal to be received is 3100 kc/sec., the next 3200, etc., until the 4 mc/sec. mark is reached. An automatic check is given by this method on the proper functioning of the multivibrator. There should be nine signals, and nine only, received between each pair of megacycle points. If not, the multivibrator is locked to an incorrect frequency, as described earlier in this series.

The same procedure may be followed in calibrating any other wave ranges on a receiver. For instance, on the broadcast band, there will be the 1000 kc/sec. signal alone, of this series, and the 100 kc/sec. points may be counted backwards and forwards from this point. Here, the frequencies of known broadcast stations may be used as a check on the calibration points. In fact, performing an experimental calibration of a broadcast receiver will make very good practice, and will at the same time constitute an excellent check on the accuracy of the frequency standard.

While calibration is in progress, it is as well to check the frequency of the 1000 kc/sec. oscillator from time to time to ensure that it has not drifted. This need not waste any time, as all that needs to be done is to turn off the multivibrator and to listen in the WWV receiver for the beat between WWV and the appropriate harmonic of the standard's oscillator. In addition, it should be remembered that this gives very great accuracy, for if WWV on 10 mc/sec. is being used, and the standard harmonic has drifted by 100 cycles/sec. or so from zero beat, this represents an error of only 10 cycles/sec. at 1000 kc/sec. or one part in a hundred thousand, which is quite good enough for a large number of purposes, but which can easily be surpassed by careful work during the calibration.

(To be continued.)

THE ROMANCE OF PLASTICS

(continued from page 7)

emergencies of wartime operation, the pressure was great to discontinue the use of natural rubber, and many new constructions were tried. The result was that these resins were used in many applications where otherwise they might never have been considered. In most instances they proved themselves so well that they will undoubtedly continue in use.

The question of its future can be answered finally and positively by the radio manufacturers, automotive producers, contractors, and construction men, who prefer it because of the simplicity of this type of insulated wire and for the outstanding job which it is capable of doing.

To summarise, its flame-proofness, light weight, high dielectric strength, and its resistance to oil, acid, and aging are so superior to natural rubber that, in the great majority of cases, we feel that the industry will find a large place for the polyvinyl resins and plastics.

TRIODE R.F. AMPLIFIER

(continued from page 15)

work well on the broadcast band, there seemed no reason at all why it should not be equally satisfactory for use on the short-wave bands. To that end it was incorporated as the first R.F. stage in a short-wave receiver which was being built with two R.F. stages, and was found to work very well indeed. This was very encouraging, since the chief use of such a circuit should be to improve the signal-to-noise ratio of short-wave receivers. In fact, this circuit in conjunction with the infinite impedance mixer, should make it possible to produce a short-wave receiver with better weak signal performance than has yet been realised by the use of conventional circuits.

THE DX BROADCAST RECEIVER

In conclusion, it may be mentioned here that the cathode coupled R.F. stage has been used in the design of the special DX broadcast receiver which we have been promising readers for some time, and which will be appearing very shortly. For this purpose, it is much more satisfactory than the 6AC7/1852, as it has an even lower noise level than this tube, and has the great advantages that no special difficulty is encountered in applying A.V.C. to it, and that making a 6AC7 behave satisfactorily on the broadcast band is a very difficult matter, which is not at all the case with the cathode coupled stage.

[References:—([1]) Szikilai and Schroeder, "Cathode Coupled Wide-Band Amplifiers." Proc. I.R.E., Oct. '45, Vol. 33, No. 10. ([2]) "The Cathode Follower at High Frequencies." "Radio and Electronics," August, 1946, Vol. 1, No. 5.]

QUESTIONS AND ANSWERS

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ing a dividing network design. We would refer Mr. Taylor, and all others interested, to an excellent article on the subject, complete with practical details, which is to be found in the January, 1946, issue of the American publication "Radio."

(3) The best choice is probably a 12in. and a 6in. speaker, as suggested in (1) above, but two 8in. speakers would give much better results than a single ordinary 12in. one.

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is to produce an electrical pressure which causes the current to flow in the circuit connected to its terminals.

In the case of the pump forcing water through a pipe, the rate of flow, or the size of the water current will depend on the pressure maintained by the pump, and on the resistance of the pipe to water flowing through it. In exactly the same way, the electric current flowing in a circuit will depend both on the electrical resistance of the circuit and upon the electrical pressure maintained by the battery or generator.

At this point, we will have to leave our story till next month, but in the meantime it will be as well to do some solid thinking about what has been said in this instalment. Visualising something that cannot be seen, like the movement of electrons in a wire, is quite a difficult matter, but it is a very necessary one if we are to work with things electrical, and more especially with radio valves.

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